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Precambrian Basement Influence on the Deposition of the Upper Ordovician Utica Shale Play in East Central Ohio

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Utica Shale Play in East Central Ohio

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ABSTRACT

The Ordovician Utica shale play is a major oil and gas producing interval in the Appalachian Basin. The Utica shale play can be found as far as New York and Canada and to the south into Indiana and Kentucky. The play consists of the Trenton/Lexington limestones, Point Pleasant Formation, and Utica shale. The shallow marine fossiliferous limestones of the Trenton and shallow marine shaley limestones of the Lexington are overlain by an interbedded shale and limestone of the Point Pleasant Formation, which grade into the deeper marine interbedded shales and limey shales of the Utica. These formations are highly heterogeneous, varying not only vertically but laterally as well. Pockets of preferential carbonate deposition in a primarily siliciclastic formation or vice versa have been noted throughout the basin, which also contain pockets of organic matter enrichment. Controls on deposition have been studied on a global (eustatic) scale, or at large scales across the basin.

This research studies the Utica shale system on a county scale, detailing potential structural influences on deposition. A combination of core and well log analyses were used to create detailed structure and isopach maps across east central Ohio. Results show that there are areas of thickening of the underlying carbonate platform (Trenton/Lexington limestones) overlain by thin fine-grained siliciclastic deposits (Utica/Point Pleasant), suggesting movement of basement blocks along pre-existing Proterozoic basement faults creating localize topographic highs and lows. The Utica shale also thickens along the northern side of the study area, suggesting that the Sebree Trough further extends into northeastern Ohio. This research: (1) helps formalize the Utica shale in Ohio; (2) provide evidence for Sebree Trough extension into northeast Ohio; and (3) further demonstrates the reactivation of structures throughout the formation history of the Appalachian Basin.

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1. INTRODUCTION

The Ordovician Utica shale play is a major oil and gas producing interval in the Appalachian Basin that consists of the Trenton and Lexington limestones, Point Pleasant Formation, and the Utica shale. The Utica shale extends from New York and Canada to Indiana and Kentucky (Smith, 2015). Although the Utica shale is known to be the source rock of many of the Paleozoic reservoirs throughout the Appalachian Basin, the Utica shale itself is a fairly new producing formation due to improved drilling techniques (Ryder, 2008).

Although the Utica shale has been widely studied since its initial description in 1842 (Ebenezer, 1842), much of the formation exists in the subsurface, with outcrops located generally within the Appalachian Mountains. The stratigraphy of the Utica shale play varies widely across the Appalachian Basin, both laterally and vertically. It is a mixed carbonate-siliciclastic set of formations that represent the change from shallow water carbonates to a deeper marine shale basin during the Late Ordovician and the Taconic Tectophase of the Taconian Orogeny (Kolata et al., 2001; McLaughlin et al., 2004). Localized depocenters of shale are found throughout the basin, such as the Point Pleasant Sub-basin within Ohio, most likely caused by topographic variations below sea level (Wickstrom et al., 2012) or along fault zones such as the Utica Fault in central Ohio (Bloxson, 2017) that have created preferential lows for increased clay-sized sediment deposition. Conversely, topographic highs still existed throughout the basin, creating areas of preferential carbonate deposition, or too shallow for clay-sized siliciclastic deposition (Bloxson, 2017). Similar to the facies distribution, organic material is also highly heterogeneous within the Utica Play, with localized lenses of material, rather than an extensive layer covering the region (Patchen, 2015), and appear to have been influenced locally by Proterozoic basement structures.

Ettensohn (2008), Quinlan and Beaumont (1984), and Beaumont et al. (1988) have showed that the Appalachian Basin basement is inhomogeneous and rife with dislocations of various ages, and that these dislocations remain zones of weakness. These zones have been shown to be reactivated when subjected to new stresses (Mitrovica et al., 1989; Coakley and Gurnis, 1995). Large-scale compression and tension and related deformational loading at the Appalachian margin during the Paleozoic closure of the Iapetus and Rheic oceans were just such stresses, causing various far-field structural displacements more than 808 mi (1300 km) from the originating orogeny (Ettensohn, 2012). With the westward subduction during the Taconian Orogeny described by Karabinos et al. (1998), the lithospheric stress regime altered to compression, so that some structural highs were uplifted, forming local unconformities, whereas deformational loads moved westward onto the craton, generating a migrating bulge and foreland basin that expanded Utica deposition westward (Ettensohn, 2012). These structural highs and corresponding lows are where facies and thickness changes could have occurred within the Utica shale system.

Detailed isopach and structure mapping of the formations in the Utica shale play can help identify various influences of the Proterozoic basement on the deposition of this mixed siliciclastic-carbonate system. Structure maps identify faults or lineaments based upon deviations in the contour lines or changes in the slope. While seismic data is ideal for identifying faults and other structural features, there is little publicly available seismic data across the region. Furthermore, while structure mapping using well log data is feasible to identify faults and other features, high-density well spacing is needed to properly identify faulting if a well does not directly penetrate the fault zone.

Isopach maps, however, have been shown to potentially identify structural features based upon locations of thinning and thickening across the region, along with detailed analysis of facies (Ettensohn, 2008). Carbonate deposition greatly depends on the base level during the time of deposition, typically deposited in a shallow, low energy environments, and cannot be deposited below the carbonate compensation depth (CCD) or below the region of sunlight penetration for organic carbonate deposition (Coniglio and Dix, 1992). The CCD dictates the depth at which carbonates can be deposited, with carbonate minerals readily dissolving below this depth. Micrite can be deposited further offshore, up until this CCD. There is a lack of reef-building organisms or other biological activity typically in deeper marine environments. Conversely, fine-grained siliciclastics are typically deposited in deep water environments, below the storm wave base and absent of carbonate buildup.

The Tanglewood Buildup is an example of the effects of water depth on carbonate versus siliciclastics deposition (Figure 1). The upper part of the Lexington Limestone in central Kentucky is a facies mosaic built around the middle and upper tongues of Tanglewood Member, which represents wave- and storm-influenced shoal complexes with major tidal reworking (Ettensohn, 2004). The Millersburg Member, composed of nodular limestones in marly shale, effectively "encapsulates" the Tanglewood and represents intermediate-ramp, shallow, open-marine environments adjacent to the shoals (Ettensohn, 2004). Other critical upper Lexington units include the Sulphur Well Member, a nodular bryozoan biostrome, and the Devils Hollow Member, a light-colored calcarenite to calcirudite that represents a carbonate, beach-barrier deposit with local, back-barrier, tidal-flat calcilutites (Ettensohn, 2004). Flanking either side of the carbonate build-ups are gradational changes to siltstone and eventually mudstones as the water depth deepened.

While mixed carbonate-siliciclastic systems can be influenced by local topography or overall sea level changes, movement along faults can create localized topographic highs and lows, which in turn can affect seawater depth. A fault could cause a block of carbonates to be up thrown. This would position the up thrown block into shallower water. This shallower water depth is preferential for carbonate deposition and causes siliciclastic deposition to be thinner on top of the up thrown block. On the adjacent sides of the up thrown block, the deeper water depth would decrease carbonate deposition. The deeper sea level would increase siliciclastics deposition. Vice versa, a carbonate block could be down-dropped. This would cause an increase in sea level depth to where siliciclastic deposition increases in the down-dropped block. The sides adjacent to the down-dropped block would be shallower in water depth. This would cause thinner deposits of siliciclastics and possibly an increase of carbonate deposition if the water depth is shallow enough. Siliciclastic formations could also be faulted, causing the formation to lower and cause an increase in sea level. This would increase accommodation space for siliciclastic deposition as well. The siliciclastic could be up thrown into shallower sea level and decrease deposition of siliciclastics on top of the lifted block.

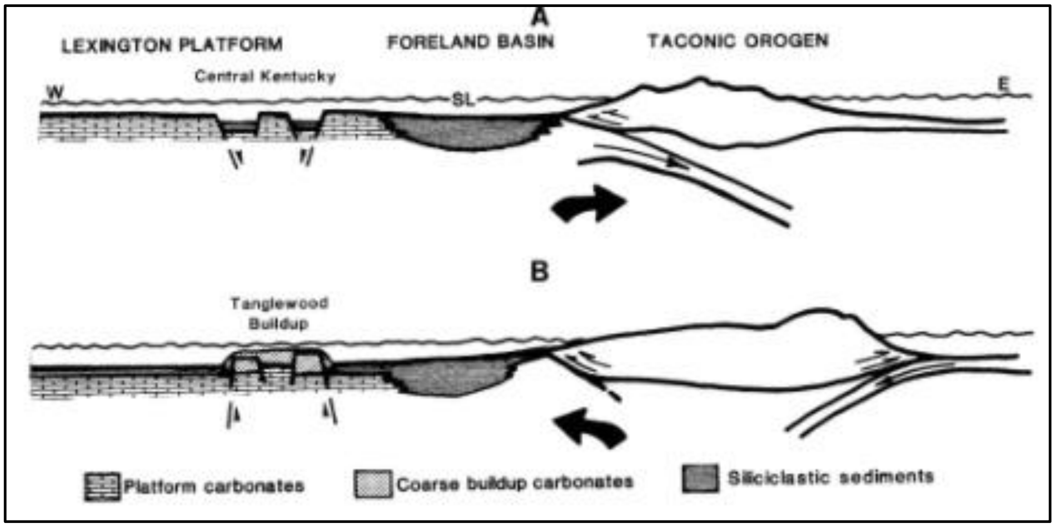

Figure 1. Diagram from Ettensohn (2004) illustrating possible origins of preeminent, far-field forces in the Taconic foreland relative to subduction polarity in the orogeny. No scale intended; positions of Lexington Platform, foreland basin, and Taconic orogeny are relative only. Thick dark arrows reflect likely direction of predominant stresses. (A) Extensional regime during early to mid-Chatfieldian time with east dipping subduction. (B) Compressional regime during late Chatfieldian to early Edenian time with west dipping subduction in the orogeny, deposition of middle and upper tongues of Tanglewood Member shown forming the Tanglewood buildup in central Kentucky.

The goal of this research was to determine the influences of the Proterozoic basement on an Upper Ordovician mix siliciclastic-carbonate system. Small-scale depositional environment changes were determined within the Ordovician Trenton Limestone, Point Pleasant Formation, and Utica shale within seven counties in east-central Ohio using a combination of core and well logging. Isopach and structure maps were created to detail facies changes, structural disruptions, and thickness changes over the area. This research contributes: (1)

to help formalize the Utica shale in Ohio; (2) provide evidence for Sebree Trough extension into northeast Ohio; and (3) further demonstrate the reactivation of structures throughout the formation history of the Appalachian Basin.

2. GEOLOGIC SETTING

During the Middle Ordovician, the Taconic tectophase of the Taconian Orogeny was occurring along the east coast of Laurentia. The Taconian Orogeny is associated with the closure of the Iapetan Ocean by the convergence of terranes and island arcs to Laurentia along the present-day east coast (Figure 2).

The Middle/Late Ordovician Black River time marks an essential change in basin architecture as the region transformed from a passive/extensional regime to a compressive regime with the east-southeast collision of the Taconic arc (Patchen et al., 2006). The architecture evolved into a broad, stable, shallow-water carbonate ramp as epeiric seas transgressed much of the region (Patchen et al., 2006). At a paleoaltitude of approximately 20° south of the equator, relatively uniform carbonates accumulated in shallow, “tropical,” warm-water seas (Patchen et al., 2006). These carbonate mudstones are lithostratigraphically consistent across most of the region west of the fore-deep associated with the Rome Trough (Patchen et al., 2006). Thick shaley carbonates were deposited within the Rome Trough-influenced fore-deep, and further to the southeast, black and gray shales dominated the Sevier Basin (Patchen et al., 2006). An archipelago of volcanic island arcs formed along the Laurentian craton margin (present-day Virginia) in response to the subduction of the oceanic lithosphere

(Patchen et al., 2006). The subduction of the oceanic lithosphere provided extensive ash deposits across the carbonate ramp, creating time-horizons across much of the continent (Patchen et al., 2006; Samson et al., 1995). The ash beds have been altered to bentonite and act as timelines because they were deposited instantaneously over a wide geographic area (Hansen, 1997). The two bentonite beds in the Middle Ordovician rocks, the Deicke bentonite, and the Millbrig bentonite, may represent some of the largest explosive volcanic eruptions in the geologic record (Hansen, 1997). These beds have been traced from the Mississippi River eastward across North America and Europe and into Russia (Hansen, 1997). These bentonite beds are particularly valuable markers for the stratigraphic columns in the Utica shale play in this research and allows for a time horizon to be determined when determining formation boundaries.

By Late Ordovician in which the Trenton Limestone was deposited, the architecture of the Appalachian Basin continued to evolve with the buildup of the Trenton and Lexington platforms surrounding what would eventually be the Utica/Point Pleasant sub-basin (Patchen et al., 2006). The craton-wide marine transgression continued as overall water depth increased while platform carbonate production kept pace (Patchen et al., 2006). The platform from Indiana/Michigan area to the central Appalachian Basin formed an overall ramp-like slope (Patchen et al., 2006). Relatively clean carbonates developed on the Trenton platform in Indiana, Ohio, Michigan, Ontario, and New York (Patchen et al., 2006). Generally, argillaceous carbonate build-ups accumulated with localized clean carbonates found throughout the Lexington platform (Patchen et al., 2006). Kolata et al. (2001) consider the Trenton and Lexington platforms near time equivalent. Nearer to the Taconic foreland basin (present-day eastern Pennsylvania and central New York), subsidence, carbonate deposition, and sediment influx were at a maximum, as evident by the very thick accumulation of relatively argillaceous Trenton carbonates in this area (Patchen et al., 2006). Carbonates of the Lexington platform display intermediate thickness and argillaceous content (Patchen et al., 2006). Carbonates accumulating on the more distal Trenton platform of northwestern Ohio, Indiana, and Michigan are thinner but display the cleanest limestone of the platforms (Patchen et al., 2006).

During the Late Ordovician Trenton/Utica time, the Taconic orogeny increased in intensity (Patchen et al., 2006). A series of bulges and down warped areas resulted, setting up shallow-water platforms and inter-platform sub-basins (Patchen et al., 2006). As relatively clean carbonates continued to be deposited upon the shallower-water carbonate platforms, interbedded limestones and calcareous shales and brown and black shales of the Point Pleasant Formation and subsequently the Utica shale were deposited within the inter-platform sub-basin (Patchen et al., 2006). The intensity of the Taconic orogeny further increased during the deposition of the Utica shale, which caused a rapid rise in sea level and/or increased subsidence of the region. It resulted in the Utica shale replacing carbonate deposition on the platforms. (Patchen et al., 2006).

In the Late Ordovician time following Utica time, the intensity of the Taconic orogeny apparently lessened and made the seas covering the region return to a more open-marine ramp environment with mixed shale and limestone deposition (Patchen et al., 2006). The depositional pattern returned once again to that established during the Black River time with the “typical” central Appalachian Basin depocenter trending north-northeast through present-day West Virginia and east-central Pennsylvania (Patchen et al., 2006). The Sebree Trough is interpreted entirely based on subsurface data from western Kentucky, southern Indiana, and western Ohio (Kolata et al., 2001). Based on a Trenton Limestone isopach map generated by Kolata et al. (2001), the Sebree Trough is approximately 93 miles wide in western Tennessee, narrowing to about 15 miles (24 km) or less in southern Indiana, a distance of about 250 miles (402 km) (Kolata et al., 2001). The trough continues northeastward another 250 (402 km) miles into northeastern Ohio (Kolata et al., 2001).

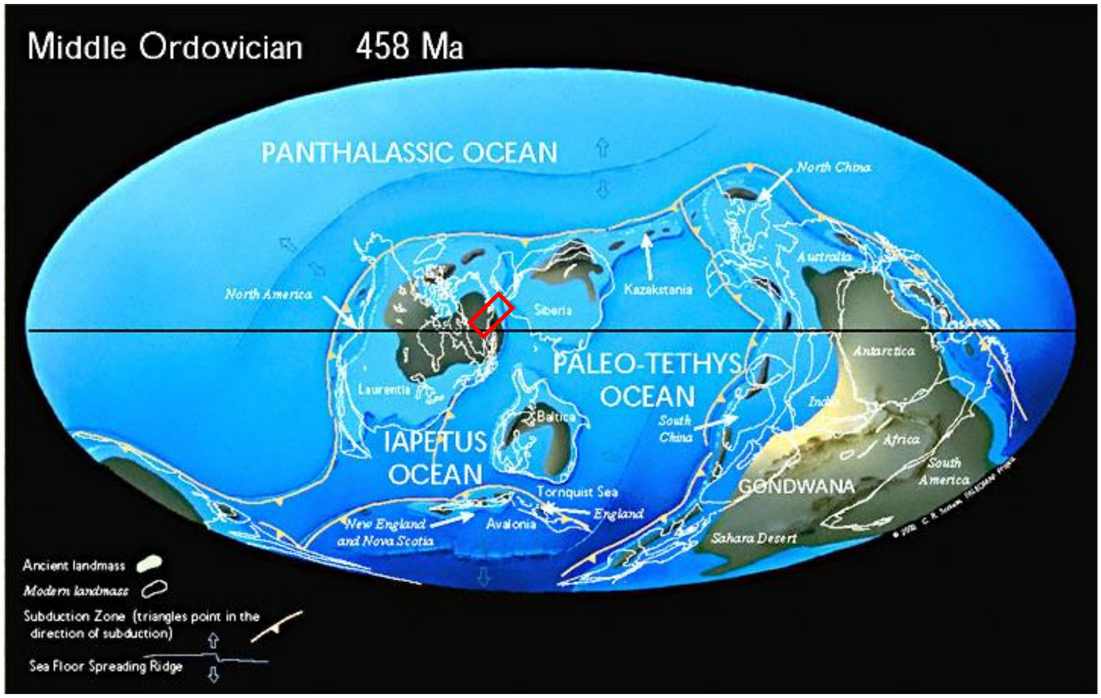

Figure 2. Paleogeographic map during the Middle Ordovician, with the red rectangle designating the Appalachian Basin. Modified from PaleoMap Project (Scotese, 2003).

The Utica shale was deposited by rapid subsidence behind the New York promontory during the convergence of microcontinents and island arcs (Ettensohn, 2008). The deposition of the Utica began to migrate west-ward due to a bulge-related unconformity. Ettensohn (2008) suggested that the migration and distribution were related to changes in subduction vergence direction. Karabinos et al. (1998) suggested that when the Utica began the west-ward migration, this caused the halting of eastward subduction because of obduction and slab break-off, which created a new westward-dipping subduction zone below the Bronson Hill arc. This west-ward subduction change caused the lithosphere stress regime to compress and structural highs to become uplifted (Karabinos et al., 1998). The deformational loads moved west-ward, generating a migrating bulge and foreland basin that expanded Utica deposition west-ward (Ettensohn, 2008).

3. STRATIGRAPHY

The Utica shale play consists of the Trenton/Lexington Limestone, Point Pleasant Formation, and Utica shale (Figure 3). For this study, the Trenton and Lexington Limestone will be combined because they are stratigraphically equivalent, and often grouped together in the Appalachian Basin region during mapping.

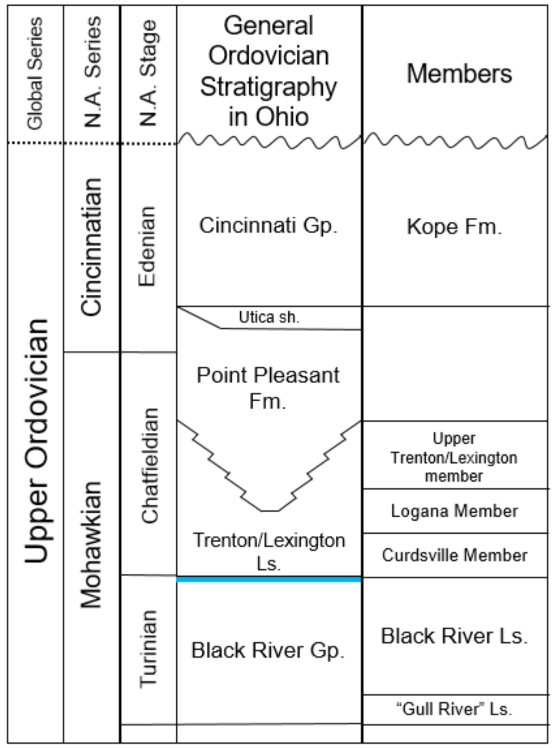

Figure 3. General Ordovician stratigraphy in Ohio. The blue line represents bentonite beds (altered ash beds) that were deposited across the region, and are the formation boundary between the Black River Group and the Trenton/Lexington limestones. Modified from Ohio Division of Geological Survey, 1990.

The underlying Black River Limestone is a fine-grained tan to gray limestone, deposited in a shallow subtidal to supratidal environment that transitioned to deeper open-marine shelf depositional environment of the Trenton Limestone and its equivalent to the south, the Lexington Limestone (Hansen, 1997). Fossils are not abundant, but occur locally (Riley et al., 2006). Chert is present locally, especially in the upper part of the unit (Riley et al., 2006). Rip-up clasts also are present locally, indicating higher-energy deposition (Riley et al., 2006). Geophysical gamma-ray-log response typically is very low in these clean carbonates with low shale content (Riley et al., 2006). Basinward, a facies change occurs where the cleaner mudstones recognized in core and on geophysical logs become more argillaceous in the deeper-water portion of the basin (Riley et al., 2006). The Black River-Trenton contact is generally a gradational zone in which Black River and Trenton lithologies are interlayered through a zone up to 10 ft. (3 m) thick (Riley et al., 2006). K-bentonites are found within the Black River through the Trenton-Lexington strata. In cores in western and southern Ohio, the Millbrig occurs near the top of the Black River and marks a change from a typical Black River bioturbated mudstone lithology to the overlying highly fossiliferous, grainstone/packstone lithology typical of the Trenton (Riley et al., 2006). On the basis of the contact in relation to the K-bentonite, the Black River-Trenton boundary appears to be diachronous (Riley et al., 2006).

The Trenton Limestone is a dark-gray to brown fossiliferous limestones with thin gray to black beds of shale deposited during the Chatfieldian stage in the Mohawkian series of the Ordovician (Ettensohn et al., 2002). There are abundant zones of secondary dolomitization (Ettensohn et al., 2002). The thickness of the Trenton Limestone ranges from 40 ft. (12 m) in west-central Ohio to 300 ft. (91 m) in northwestern Ohio (Ettensohn et al., 2002). Clean Trenton carbonate grainstones, packstones, and wackestones were deposited on the western side of the Trenton platform in what is now Michigan, Indiana, and northwestern Ohio (Patchen et al., 2006). However, farther to the east and north, in Ontario and New York, carbonate grainstones, packstones, and wackestones are more argillaceous, although the sharp upper contact present in the west continues through this eastern area (Patchen et al., 2006). To the south, however, where argillaceous grainstones, packstones, and wackestones were being deposited on the Lexington platform, the contact is more gradational (Patchen et al., 2006). Fossils commonly found are bryozoans, brachiopods, trilobites, and crinoids.

The Lexington Limestone is a shaley limestone that was deposited during the Chatfieldian stage in the Mohawkian series of the Ordovician (Ettensohn et al., 2002). The thin Lexington Limestone typically ranges from 0-30 ft. (0-9 m) in Ohio and can be up to 200-320 ft. (61-98 m) thick outside of Ohio (Figure 4) (Ettensohn et al., 2002; Cressman, 1973). Both limestones were deposited on a platform to an open-shelf marine environment in the presence of relatively cool water (Kolata et al., 2001; Brookfield, 1988; Patzkowsky and Holland, 1993; Lavoie, 1995 Hansen, 1997). The Lexington Limestone platform is a deeper water platform than the Trenton platform in northwestern Ohio, as indicated by more argillaceous material and a more gradational upper contact with the overlying Point Pleasant (Patchen et al., 2006). Total Organic Carbon (TOC) values of the limestones can be as high as 4-5% (Smith, 2015). The Lexington Limestone is an argillaceous limestone with a mixture of high and low TOC values (Smith, 2015). The common fossils found in the formation are ostracods and trilobites, with bryozoans and crinoids more common at the top of the formation (Smith, 2015).

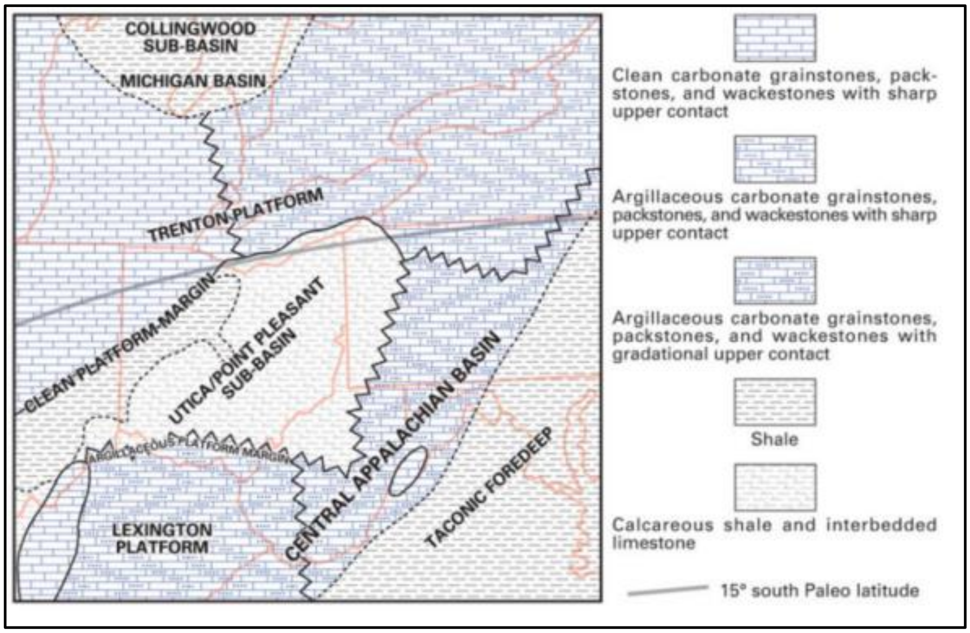

Figure 4. Diagram of the Appalachian Basin during the Late Ordovician from Brinkley (2016).

The Trenton Limestone and Lexington Limestone were deposited roughly around the same time during the Mohawkian series (Kolata et al., 2001). During the deposition of these limestones, the Sebree Trough was developing during the late Turinian to early Chatfieldian time as a linear bathymetric depression situated over the failed lLate-Precambrian/Early-Cambrian Reelfoot Rift (Kolata et al., 2001). The Sebree Trough extends from the margin of the Laurentian Craton in central Arkansas northeastward into southern Illinois before turning abruptly eastward, continuing as the Rough Creek graben in western Kentucky (Kolata et al., 2001). The Black River carbonate sedimentation kept pace with rift subsidence, but by latest Turinian to early Chatfieldian time, sedimentation stopped, drowning commenced, and facies changed from predominantly lime mudstone and skeletal wackestone to graptolitic shales, and the Sebree Trough began to form (Kolata et al., 2001). After it formed, the trough sustained itself because of the contrasting slow shale sedimentation within the bathymetric trough and relatively rapid rates of carbonate sedimentation on the flanking Lexington and Galena platforms (Kolata et al., 2001). The trough trapped fine siliciclastic sediments that were shed from Taconian highlands which resulted in trough separating the siliciclastic rich carbonates of the Lexington platform from the pure skeletal carbonates of the Galena platform (Kolata et al., 2001). The Trenton/Lexington limestones grade laterally into each other and upward to either predominantly dark-gray to brown-to-black, platy, finely-laminated, locally calcareous Utica shale and interbedded limestone or calcareous shales of the Point Pleasant Formation (Patchen et al., 2006).

Overlying the Trenton and Lexington limestones and underlying the Utica shale is the Point Pleasant Formation. The Point Pleasant Formation is named for the interbedded gray shales and limestones exposed near Point Pleasant, OH (Patchen et al., 2006, Smith, 2015). It extends northward beneath the Utica shale and comprises interbedded fossiliferous limestone, shale, and minor siltstone (Smith, 2015). The limestone and shale occur in roughly equal amounts, whereas the siltstone accounts for only a small unit percentage (Smith, 2015). The Point Pleasant interval is equivalent to the lower Clays Ferry Formation of Kentucky and the lower Indian Castle Shale of New York (Smith, 2015). The Point Pleasant Formation was deposited during the middle Mohawkian to early Cincinnatian series. It extends from southern Ohio and West Virginia to most of northern Ohio and northwestern and north-central Pennsylvania (Brinkley, 2016). TOC values can be as high as 4-5% for the Point Pleasant. The formation has been divided into two sub-groups (Smith, 2015), an upper organic-poor and lower organic-rich section. The upper organic-poor section contains thin carbonate beds that commonly contain bryozoans and has an abundance of storm bed deposits and diverse, open marine fauna. The lower organic-rich Point Pleasant is 40%-60% carbonate with numerous storm beds and burrows (Smith, 2015).

The Utica shale consists of interbedded dark fissile shale and limey shale (10-60% calcite) beds that were deposited in a deep marine environment during the Cincinnatian series in the Appalachian Basin (Smith, 2015). These beds tend to be bioturbated, and can be fossiliferous in part (Smith, 2015). The Utica shale represents a major transgression across the eastern United States, and the shales indicate a large influx of organic material, restricted circulation, and low-energy conditions (Patchen et al., 2006). The Utica shale extends from southern Ohio and West Virginia towards the southwest near the Kentucky-Indiana border, and to the north through New York and partially into Canada (Brinkley, 2016). In Kentucky, the Utica shale interval is equivalent to the upper Clays Ferry Formation, whereas in New York it is stratigraphically equivalent to the upper Indian Castle Shale (Smith, 2015). In outcrop in the Appalachian fold belt, the

Antes Shale and Martinsburg Formation occupy the same stratigraphic level of the Utica (Smith, 2015). The Utica shale pinches out to the south in southern Ohio and West Virginia but extends along the “Sebree Trough,” roughly coinciding with the Kentucky/Indiana border (Smith, 2015). A typical thickness for the Utica in eastern Ohio ranges from 180-230 ft. (55-70 m) but thickens to the northeast to approximately 400 ft. (121 m) in east-central New York (Smith, 2015). The thickest part of the Utica shale is over 700 ft. (213 m) in the Rome Trough region of Pennsylvania (Patchen et al., 2006). The Utica shale is partially coeval with the Trenton Limestone of the platform and entirely coeval with the Point Pleasant Formation of the Utica/Point Pleasant Sub-basin area (Patchen et al., 2006). The Utica shale is absent over most of the Lexington platform due to facies transition with overlying gray shale of the Kope Formation (Patchen et al., 2006). TOC values are usually greater than 1 % (weight %) and follow a northeast trend of 2-3 % TOC values in eastern Ohio (Ryder, 2008). The mineralogy for the Utica shale is typically 25% carbonate content which contains brachiopod fossils (Smith, 2015). The Utica shale has very little storm beds due to the depth of water when it was deposited below the storm wave base (Smith, 2015). Locally, the Utica and Point Pleasant display an intertonguing relationship (Patchen et al., 2006).The Point Pleasant and Utica intertounge in part with the Lexington/Trenton Formation (Patchen et al., 2006).

4. METHODS

The study area consists of seven counties in eastern Ohio (Carroll, Columbiana, Harrison, Jefferson, Mahoning, Portage, and Stark) (Figure 5). A core sample as well as well logs were used for the study. This study combines the Trenton and Lexington limestones into one unit for mapping.

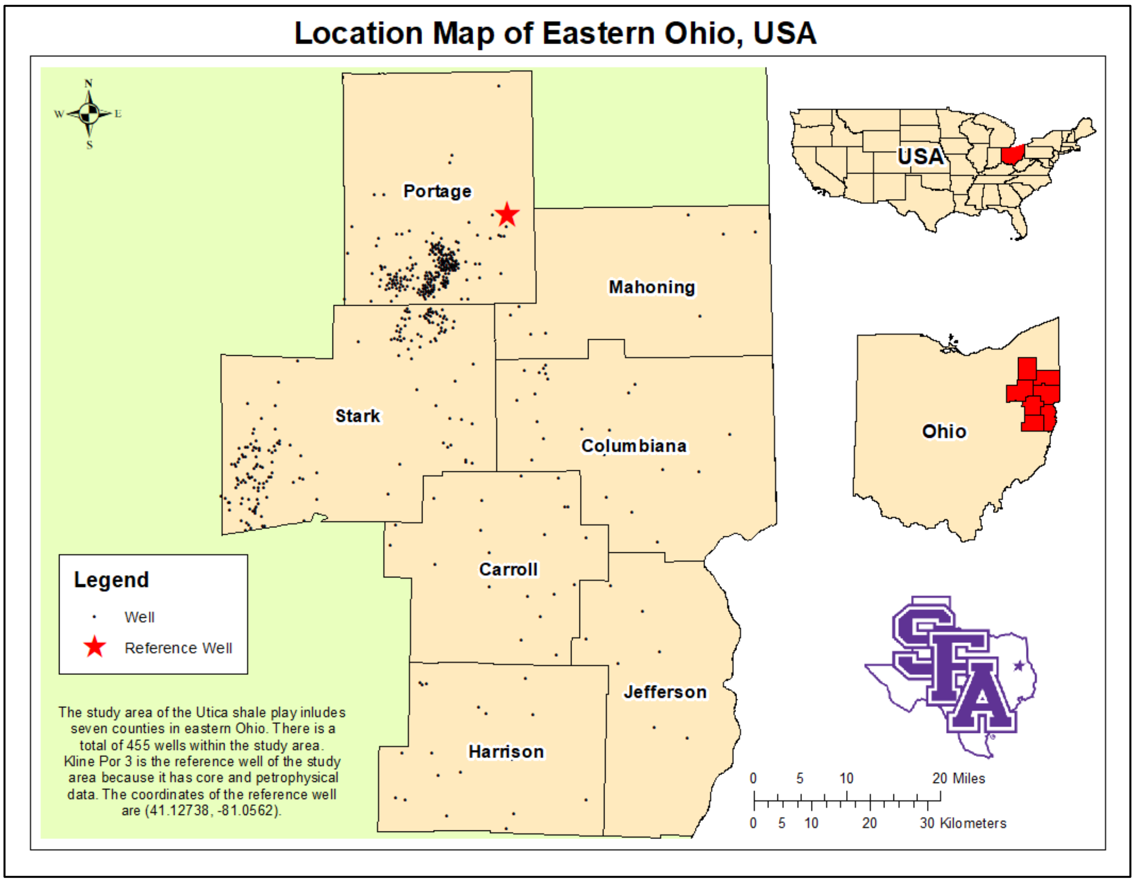

Figure 5. Study area in Eastern Ohio consisting of Carroll, Columbiana, Harrison, Jefferson, Mahoning, Portage, and Stark counties. The red star is the location of the reference section Kline Por 3 core.

4.1 Core Logging

A core donated by Tracker Resource Development from Kline Por 3 well located in Portage County, Ohio was used in this study. This core is archived at the Ohio Geological Survey, Columbus, OH (Core No. 6434; API. 34133244490000). The cored interval consists of 6,141 ft-6,474 ft. (1,872 m-1,973 m), containing 30 ft. (9 m) of the Trenton Limestone, 87 ft. (27 m) of the Point Pleasant Formation, and 216 ft. (66 m) of the Utica shale. The core was described every 10 ft. (3 m), focusing on the overall formation transitions from the lowest core depth to the shallowest core depth. Lithologies, color, fossils, storm beds, and laminations were recorded. The core was then correlated to the corresponding well log data to provide a reference log (Figure 6).

4.2 Well Logging

A total of 455 well logs were used for this study, publicly available from the Ohio Department of Natural Resources, Division of Geological Survey. The gamma ray and density logs were the primary data used to determine formation boundaries. Several locations contained neutron porosity and PEF log measurements.

The formation boundaries were delineated using Petra and were based on gamma ray and density value changes similar to the reference log of Kline Por 3 in Figure 6. The contact between the Black River Group and the Trenton/Lexington Limestone was determined by the presence of a bentonite bed in the midst of a carbonate formation. The bentonite bed is shown on the well log by a sharp increase in gamma ray values, and a sharp decrease in density value.

The contact between the Trenton Limestone and Point Pleasant was determined by a change from clean carbonate and argillaceous grainstones, packstones, and wackestones into more shaley limestone interbedded with shales. This is represented by changes in the gamma ray log and density log. The clean carbonate grainstones, packstones, and wackestones of the Trenton display a sharp contact with the overlying Point Pleasant Formation. The geophysical log curves for the formation boundary shows an increase in gamma ray. The gamma ray increase is due to the increased amount of clay content, which typically is the primary source for radioactivity in these formations (K, U, and Th are most often associated with clay minerals and shales within the Upper Ordovician System). The density changes from a high carbonate density to a slightly lower density of the mixed siliciclastics, representing a decrease in higher-density carbonate material in the formation.

The argillaceous grainstones, packstones, and wackestones of the Lexington Limestone display a gradational contact with the overlying Point Pleasant Formation. The argillaceous carbonates formation boundary of the Lexington and the mixed siliciclastics of the Point Pleasant is gradational on the gamma ray curve. This is because of the argillaceous carbonates containing more clay minerals than the clean carbonates, eventually grading into the more siliciclastic rich Point Pleasant. The gamma ray value slightly increases transitioning into the

Point Pleasant, but the formation boundary is marked by a decrease in density from the Trenton/Lexington to the Point Pleasant. The Point Pleasant is 40-60% carbonate in the lower organic-rich portion but overall is equal parts mixed shale and fossiliferous limestone.

The formation boundary between the Point Pleasant and the Utica is not easily distinguishable. The gamma ray curve increases while moving towards the Utica/Point Pleasant formation boundary. The sudden dip or “shale break” in the gamma ray curve is where the formation boundary was determined—the mixed siliciclastics of the Point Pleasant transition into a primarily shale formation of the Utica. The density stays fairly consistent between the Point Pleasant and Utica, except where there is increased organic content.

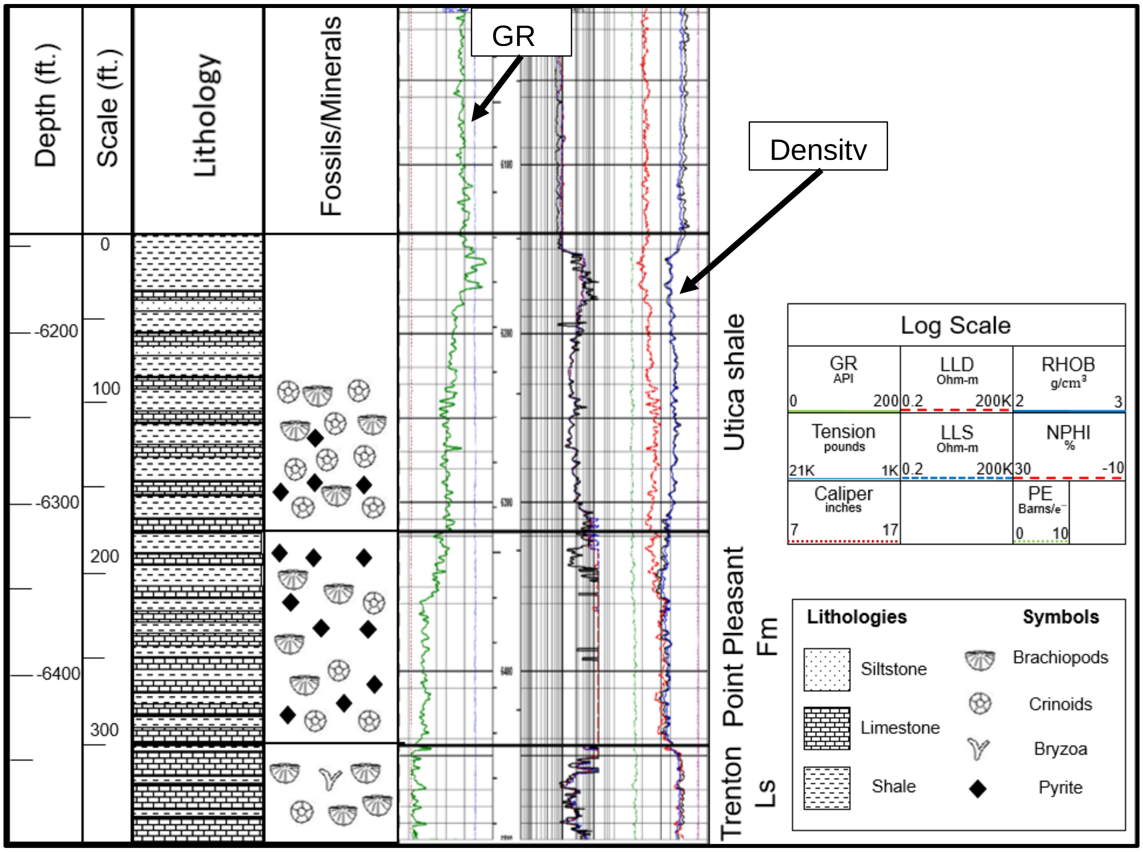

Figure 6. Reference log of Ohio displaying the formations within the Utica shale play. Reference log is based upon the data from Tracker Resource Development Kline Por 3 well. The lithological description for the core is to the left to showcase the changes in lithology and their correlation to the well log data. Black star designates pyrite. The curves from the log and the log scale correlate to the appropriate tracks.

4.3 Mapping

Structure and isopach maps were created for the Trenton/Lexington Limestone, Point Pleasant Formation, and Utica shale. Depths to the formation boundaries were determined in Petra, and exported into ArcGIS from ESRI for final mapping. The isopach values were calculated by subtracting the depth of the upper formation boundary from the depth of the lower formation boundary. Structure maps were created based upon subsea level depth values of the top formation boundary.

Both types of maps were contoured in ArcGIS. The wells and associated data were imported into ArcGIS. Then Simple Kriging in Geostatistical Wizard was used in ArcGIS to create raster images for the maps, with an output surface type of prediction. The Kriging tool fits a mathematical function to a specified number of points, or all points within a specified radius, to determine the output value for each location. Kriging is a multistep process; it includes exploratory statistical analysis of the data, variogram modeling, creating the surface, and exploring a variance surface. The contour tool was then used to contour the exported raster that was made for each structure and isopach map. After contouring the raster, the contours were smoothed and clipped to only display the contours within the study area. Contours are lines that connect locations of equal value in a raster dataset that represents continuous phenomena such as elevation, temperature, or precipitation. The line features connect cells of a constant value in the input. The points are separated by contour lines based on the value of the contour lines and the value of the points. Topo to Raster tool was used to create a new raster from the smoothed contours in the study area. The finished raster's were shaded to display depth variations in the structure maps and display changes in thickness in the isopach maps. Known faults from Baranoski (2002) and lineaments from Solis (2016) were overlaid on the structure and isopach maps.

5. RESULTS

5.1 Core Description

The Tracker Resource Development Kline Por 3 core consists of the upper portion of the Trenton Limestone, and the entire sections of the Point Pleasant Formation and Utica shale. The core consists of the depth interval 6,141 ft-6,474 ft. (1,872 m-1,973 m). The Trenton Limestone cored interval ranges from 6,444 ft-6,474 ft. (1,964 m-1,973 m) in depth, the Point Pleasant Formation interval spans 6,357 ft-6,444 ft. (1,938 m-1,964 m), and the Utica shale consists of 6,141 ft-6,357 ft. (1,872 m-1,938 m).

The core displays only 30 ft. (9 m) of the Trenton Limestone from 6,444-6,474 ft. (1,964 m-1,973 m) (Figures 7). The Trenton Limestone is mostly light to medium grey in color with frequent shell hash beds as well as storm beds. The limestone becomes less fossiliferous, moving from the bottom to the top of the Trenton Limestone. Thin layers of medium to dark grey shale are common and frequent throughout the section. Microcrystalline and sparry calcite crystals, similar to the fossils, become less abundant, moving from the bottom of the Trenton Limestone to the top. The fossils are primarily brachiopods with occasional crinoid and bryozoan.

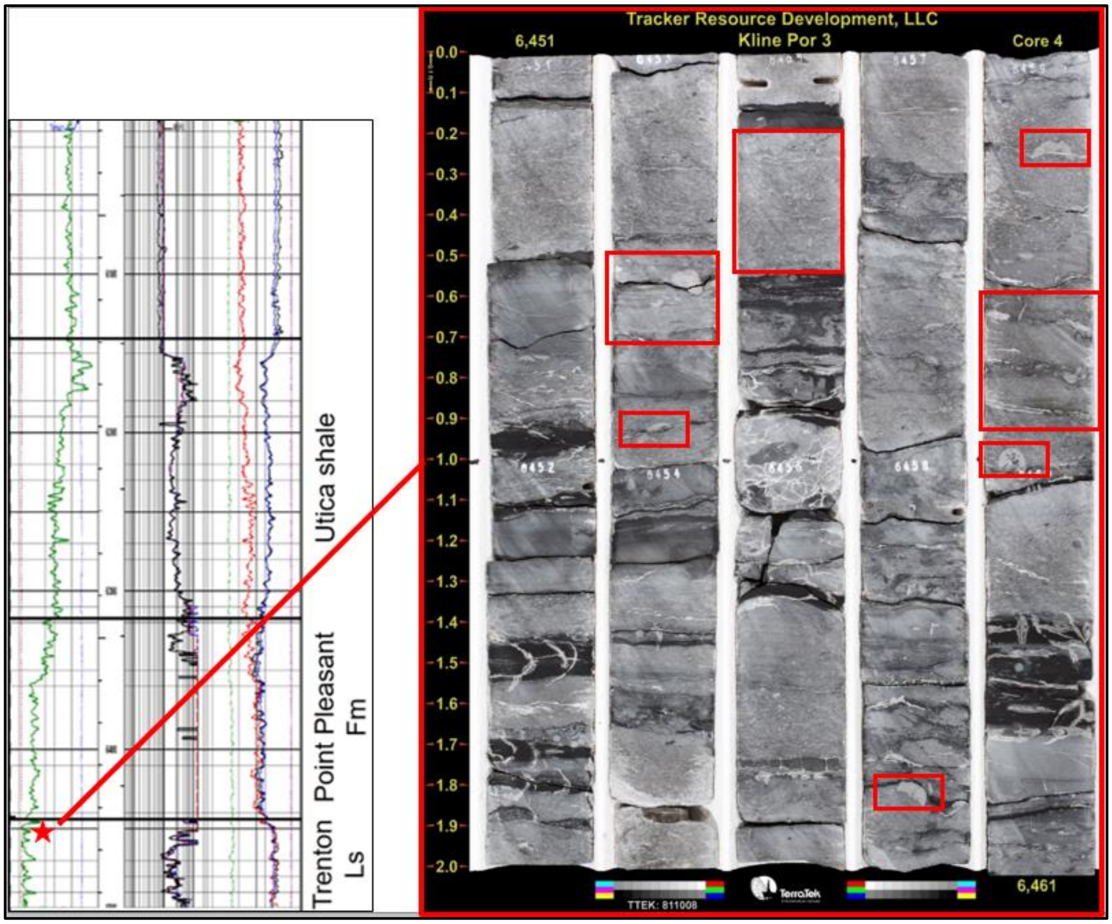

Figure 7. Slab pack core sample of Kline Por 3 well in Portage County, Ohio. Interval is 6,451-6,461 feet. Photos were taken by Terra Tek. Red boxes indicate examples of whole fossils found. Fossils seen in the figure are crinoids, brachiopods, and foraminifera. Red star indicates where the image is located on reference log.

The Point Pleasant Formation ranges from 6,357-6,444 ft. (1,938 m-1,964 m), consisting of 87 ft. (27 m) (Figures 8&9). The Point Pleasant is primarily a medium to dark grey calcareous shale. The shale laminations are generally planar, but wavy, cross-bedded, and angular beds are common throughout. The thin limestone beds that occur are medium to dark grey in color, similar to the limestone in the Trenton. These storm beds still occur but become more frequent moving upward in the core. Fossils found in the storm beds are broken pieces that are not oriented in a specific direction. This could be from high-energy storms that upwelled organisms and then the organisms settled differently. Pyrite is found in the lower section of the Point Pleasant but is more abundant in the upper section of the core. The common fossils found within the Point Pleasant are graptolites, brachiopods, and crinoid stems. The formation boundary between the Trenton and Point Pleasant is gradational but was determined on the transition from a carbonate to more siliciclastic. At 6,444 ft. (1,964 m) depth, the lower part is a light grey carbonate with a dark shale in the middle. Moving upsection to 6,443 ft. (1,963 m), the core becomes more siliciclastic.

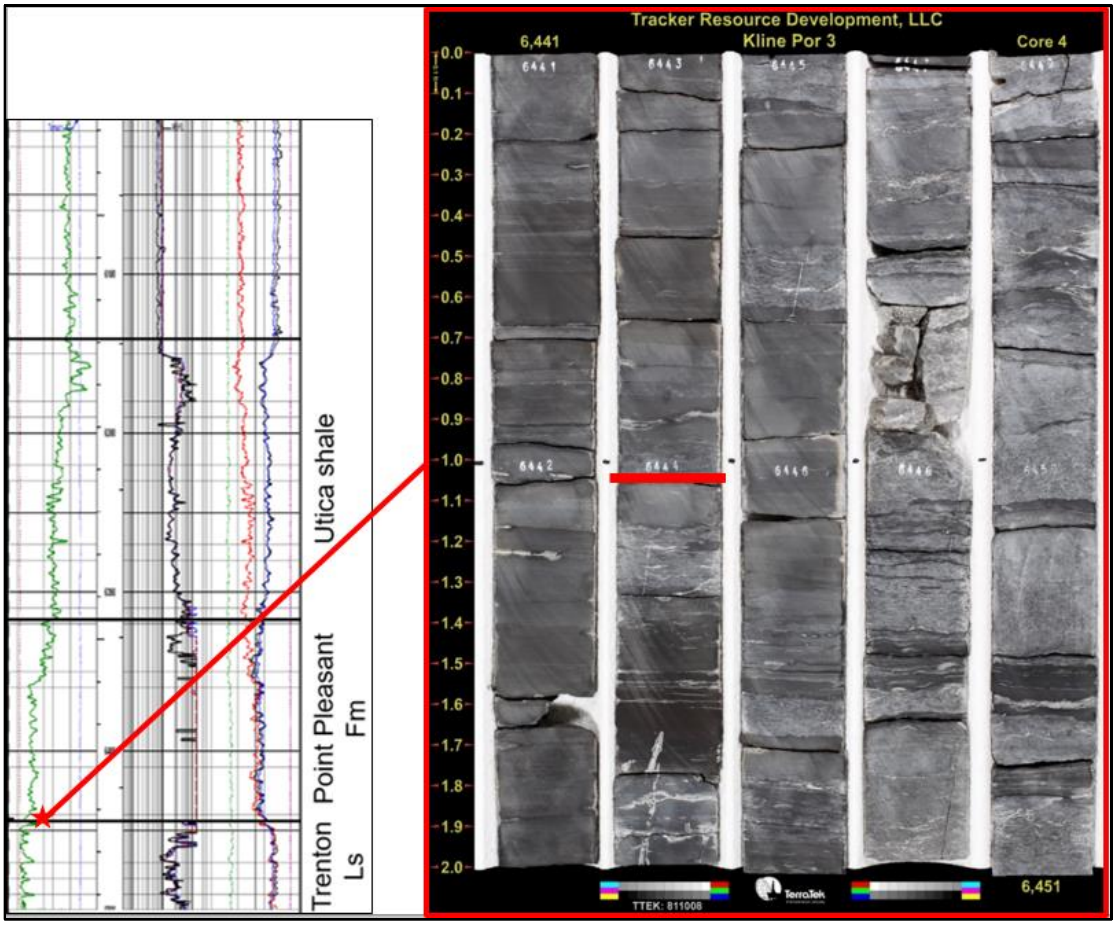

Figure 8. Slab pack core sample of Kline Por 3 well in Portage County, Ohio. Interval is 6,441-6,451 feet. Photos taken by Terra Tek. Red line on the core image indicates the formation boundary between the Point Pleasant and Trenton. The picture shows the transition from the Trenton to Point Pleasant, where there is a marked increase in siliciclastic content compared to the lower Trenton Limestone. Red star indicates where the image is located on reference log.

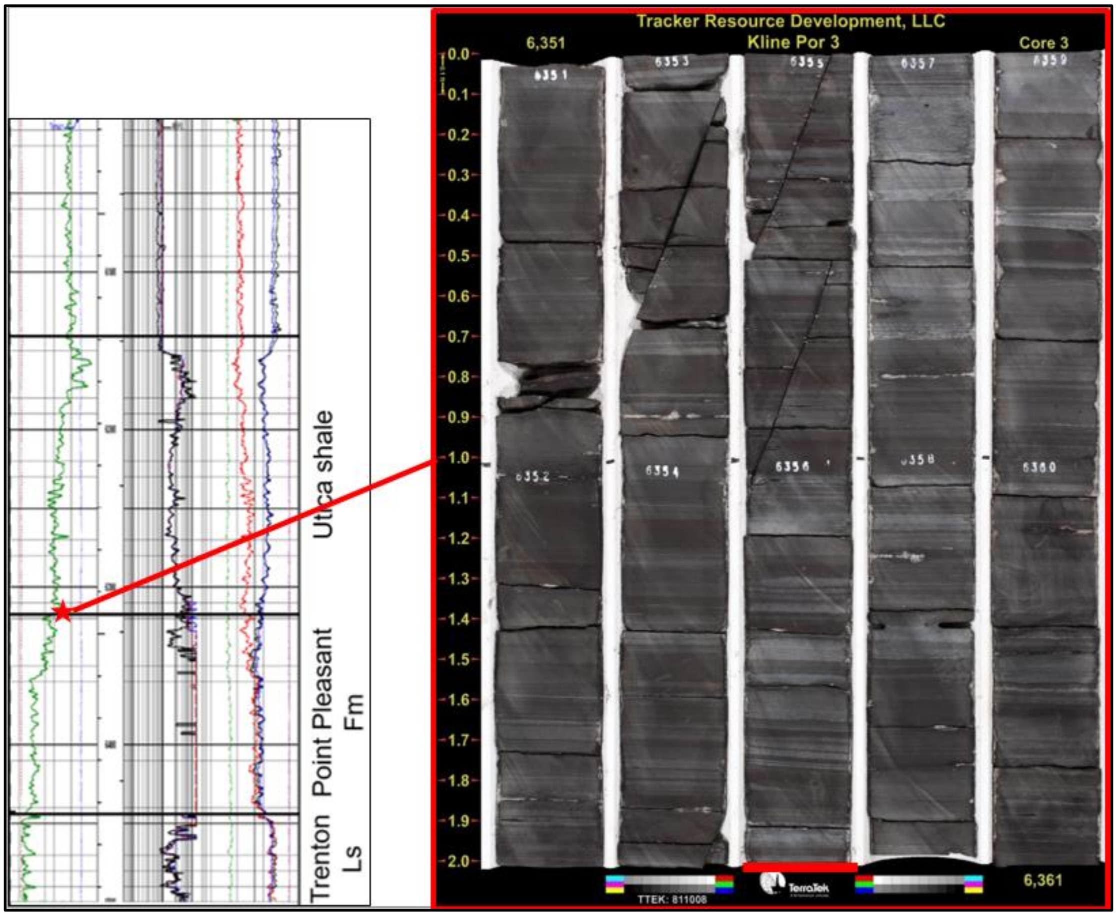

Figure 9. Slab pack core sample of Kline Por 3 well in Portage County, Ohio. Interval is 6,351-6,361 feet. Photos taken by Terra Tek. The red line on the core image indicates the formation boundary between Utica and Point Pleasant. The core picture shows the transition from the Point Pleasant to the Utica. Red star indicates where image is located on reference log.

The Utica shale is the thickest formation in the core, ranging from 6,141-6,357 ft. (1,872 m-1,938 m) (Figures 10 & 11). The 216 ft. (66 m) thick shale is medium to dark grey in color. Fossils are abundant in the middle to lower section of the Utica and are less common in the upper portion. Laminations in the Utica are typically planar but can be cross-bedded or wavy. Fossils found in the Utica are primarily crinoids and brachiopods with occasional articulated trilobites and graptolites. The carbonate layers are thin laminations that are light to medium grey. They tend to be fossiliferous and contain occasional laminations of sparry calcite along a bedded plane. Most of the non-planar laminations are associated with the carbonates. Storm beds still occur but become less frequent moving upward in the core. Pyrite is common either as a replacement to the fossils or as nodules. Calcite laminations are light grey to very light grey or white and are occur occasionally throughout the Utica. Wetting the core shows color differences between grey and brown, particularly within the first 40 ft. (12 m) of the Utica shale. Brown layers found within the Utica do not contain calcite. These brown layers are most likely siltstone beds, and are rare.

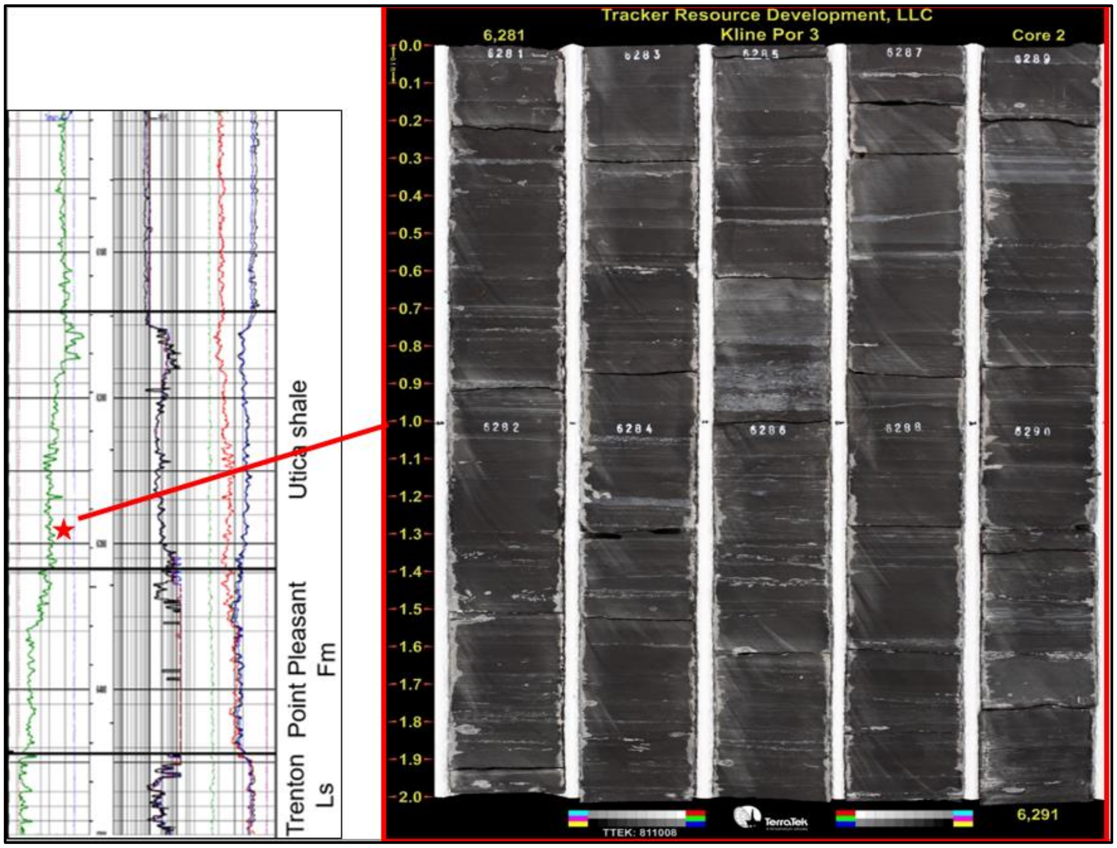

Figure 10. Slab pack core sample of Kline Por 3 well in Portage County, Ohio. Interval is 6,281-6,291 feet. Photos taken by Terra Tek. The picture is from the lower Utica and shows primarily dark shales with some carbonate laminations and shell hash beds. Red star indicates where core is located on reference log.

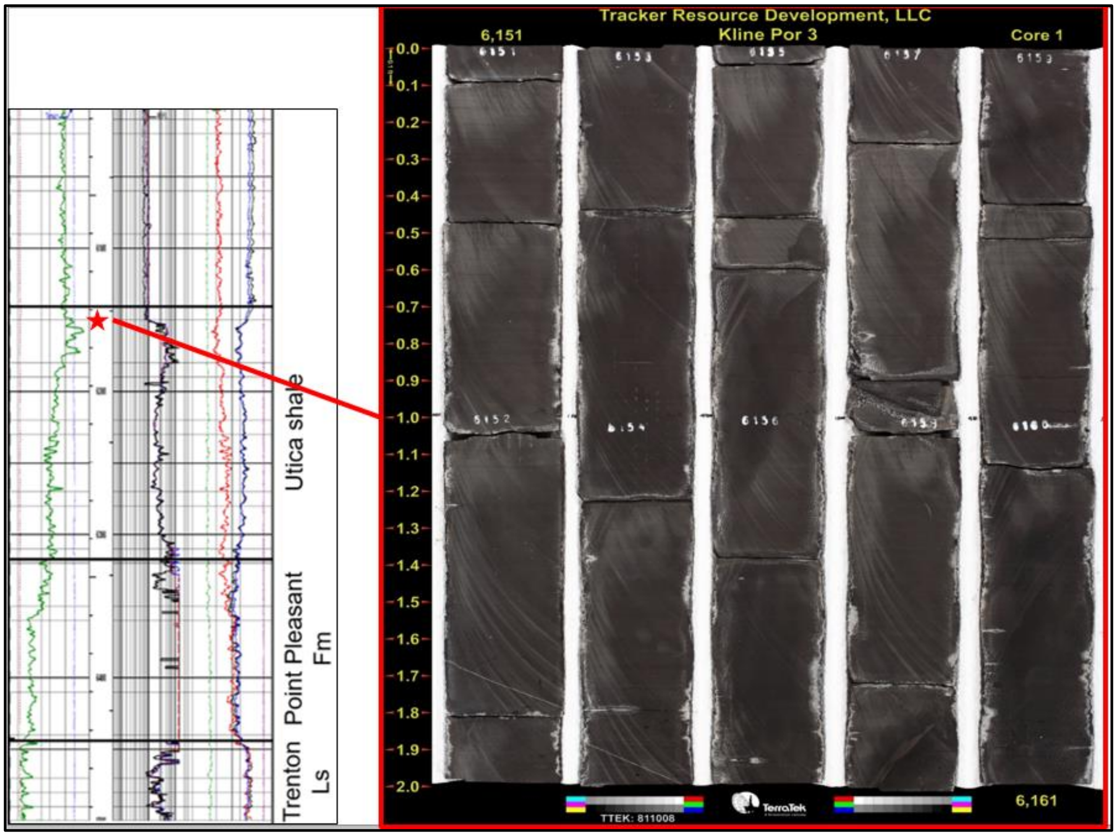

Figure 11. Slab pack core sample of Kline Por 3 well in Portage County, Ohio. Interval is 6,151-6,161 feet. Photos taken by Terra Tek. This picture shows the upper Utica. The upper Utica is primarily dark shale with very little carbonate laminations. Red star indicates where core is located on reference log.

5.2 Structure Maps

There are 12 known faults and 51 known lineaments throughout the study area (Figures 12-14), as determined by Baranoski (2002) and Solis (2016). The faults were determined by Baranoski by a combination of public and private literature, well data from Ohio and outside of Ohio, and approximately 500 miles (804 km) of public-domain and restricted seismic-reflection data. Baranoski also used approximately additional 100 miles (160 km) of proprietary and published seismic data that were used to delineate or verify faults and structures. The lineaments were interpreted based on structure maps of the Upper Devonian Berea sandstone, Middle Devonian Onondaga Limestone, and Silurian Dayton Formation (Solis, 2016), which consisted of 55,000 to 120,000 data points across eastern Ohio. Slopes were calculated in ArcGIS, and lineaments were placed where the change in slope reached a certain threshold. When describing the structure maps, “structural features” are those that show a change in the slope from the surrounding area, giving the appearance of disruptions in the contours.

The Trenton/Lexington Limestone is shallowest in western Stark County and northwestern Portage County where the depths are shallower than -4,600 ft. (-1,402 m) (Figure 12). The formation is deepest in the southeast, where depths exceed -7,500 ft. (-2,286 m). The structure map shows a dip in a northwest-southeast trend. Portage County has four structural features shown. The first is located in central Portage County and has a northwest-southeast trend (P1). The next three is located in the southwest portion and has a similar trend as the first set (P2-P4). Stark County has three sets of structural features. The first is located in northern Stark County and has a northwest-southeast trend (S1). This set runs into southern Portage County and continues outside the study area. Sets two and three are located beside each other in southwestern Stark County and have an east-west trend (S2-S3). Carroll County has one set of structural features located in the west-central and has a northwest-southeast trend (C1). Columbiana County has three sets of structural features. Two are located beside each other in the central portion of the county (Co1-Co2). These two sets display a northwest-southeast trend. The final set is located in southern Columbiana County and runs through northwestern Jefferson County (Co3). This set has a similar trend to the first two sets. Harrison County has one set of structural features in the southern portion of the county (H1). This set displays a northwest-southeast trend.

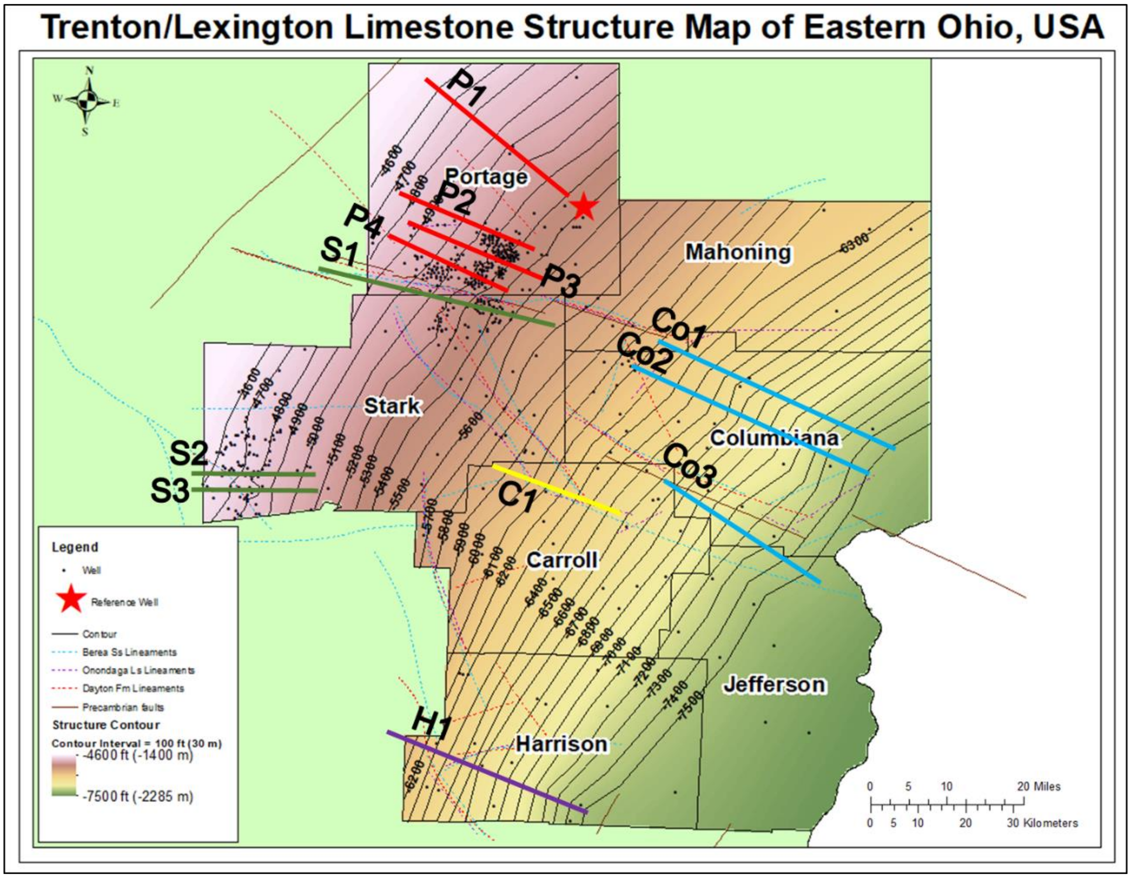

Figure 12. Structure map of the Trenton/Lexington Limestone. Faults are from Baranoski (2002) and lineaments are from Solis (2016). Structural features are identified by solid colored line and labeled with abbreviation and number. Note: P1 – Portage County 1; P2 – Portage County 2; P3 – Portage County 3; P4 – Portage County 4; S1 – Stark County 1; S2 – Stark County 2; S3 – Stark County 3; C1 – Carroll County 1; Co1 – Columbiana County 1; Co2 – Columbiana County 2; Co3 – Columbiana County 3; H1 – Harrison County 1

The Point Pleasant Formation structure map is shallowest in the northwest of the study area, where depths are above -4,500 ft. (-1,372 m) (Figure 13). The formation is deepest in the southeast, where depths exceed -7,400 ft. (-2,256 m). The structure map displays a dip in a northwest-southeast trend. Portage County has two sets of structural features (P1-P2). They are located in the central portion of the county and have a northwest-southeast trend. Stark County has three sets of structural features. The first is located in northern Stark County that runs into southern Portage County, and extends outside the study area in a northwest-southeast trend (S1). The second and third sets are located in the southwestern portion of Stark County (S2-S3). Both sets are right next to each other and have an east-west trend. Carroll County has two sets of structural features, with both sets having a northwest-southeast trend. One is located in the western portion (C1), and the second is located in the northeastern portion of the county (C2). Columbiana County has two sets running beside each other in central Columbiana (Co1-Co2). Jefferson County has one set of structural features in the northwestern portion with a northwest-southeast trend (J1).

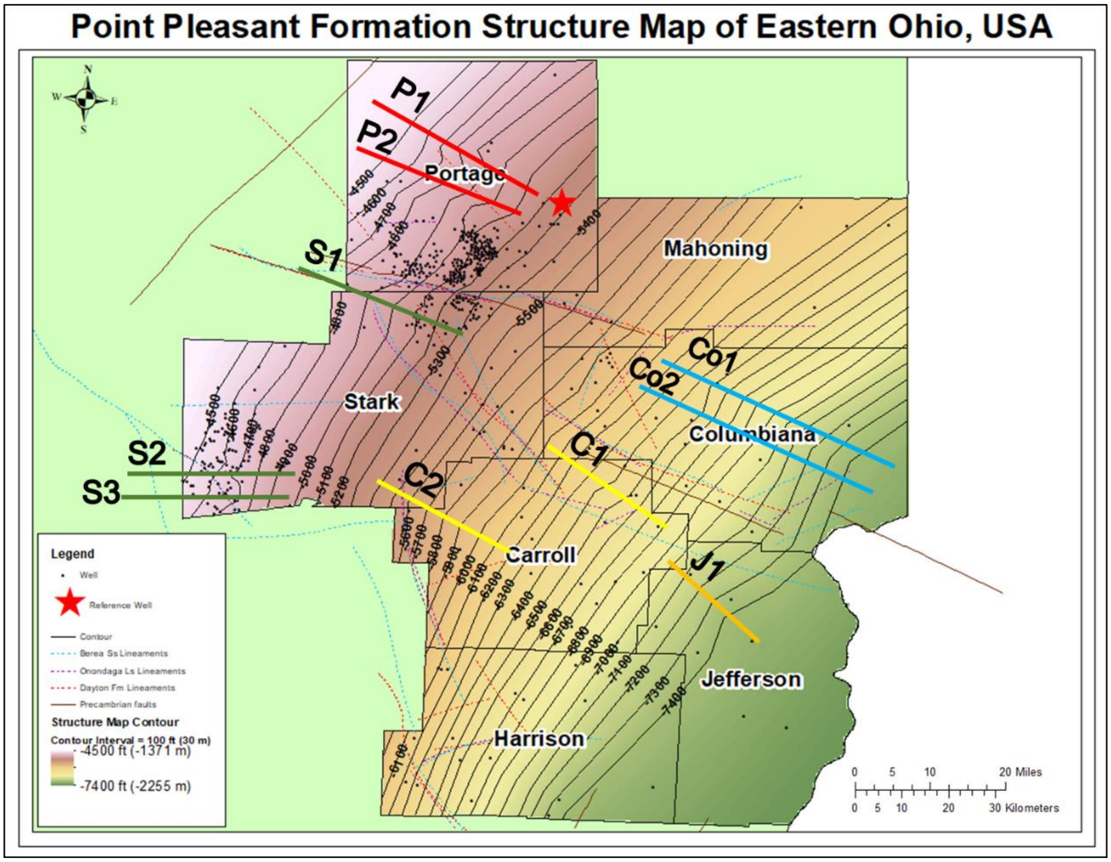

Figure 13. Structure map of the Point Pleasant Formation. Faults are from Baranoski (2002) and lineaments are from Solis (2016). Structural features identified by solid colored line and labeled with abbreviation and number. Note: P1 – Portage County 1; P2 – Portage County 2; S1 – Stark County 1; S2 – Stark County 2; S3 – Stark County 3; C1 – Carroll County 1; C2 – Carroll County 2; Co1 – Columbiana County 1; Co2 – Columbiana County 2; J1 – Jefferson County 1

The Utica shale structure is shallowest in the northwest portion of the study area, where the depths are shallower than -4,300 ft. (-1,311 m) (Figure 14). The deepest portion of the Utica shale is in the southeast portion, where depths are deeper than -7,200 ft. (-2,195 m). The same northwest-southeast dipping trend is shown in the Utica shale structure map. There are three structural features in Portage County. The first and second are in the central portion of the county and trend northwest-southeast (P1-P2). The third structural feature is located in the southern portion of Portage and the northern portion of Stark County (P3). The trend of this set of structural features is northwest-southeast similar to the set of structural features found in central Portage County. Western Stark County shows four sets of structural features, where three trend northwest-southeast and one set trending west-east direction (S1-S4). Columbiana County shows four structural features. The first two sets are located in the north-central part of the county, where one has a northwest-southeast trend and the second has a west-northwest to east-southeast trend (Co1-Co2). The third and fourth set is located in the south-central part of the county and has a northwest-southeast trending direction (Co3-Co4). Carroll County has two structural features located in the central and northeastern portions of the county (C1-C2). These two sets trend in the northwest-southeast direction similar to the overall dip. Harrison County has one structural feature where the trend is similar to the overall dip (H1).

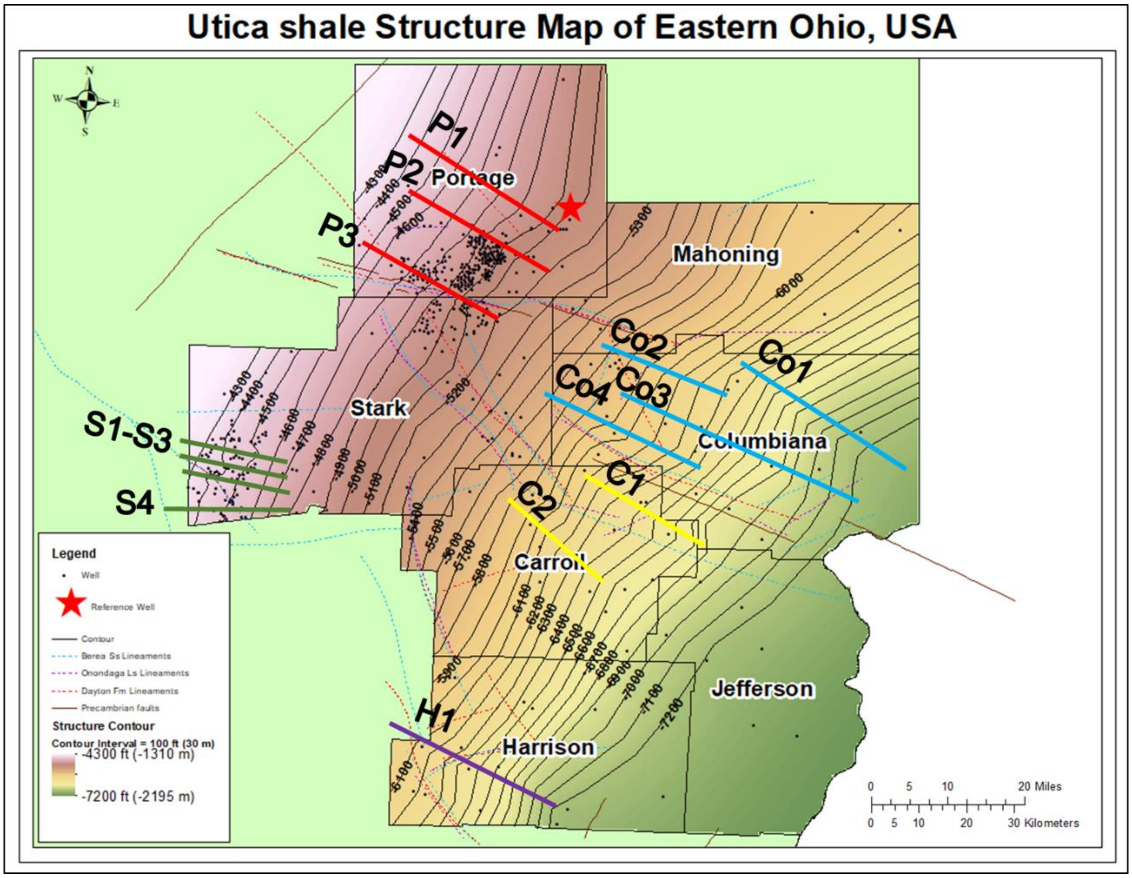

Figure 14. Structure map of the Utica shale. Faults are from Baranoski (2002) and lineaments are from Solis (2016). Structural features identified by solid colored line and labeled with abbreviation and number. Note: P1 – Portage County 1; P2 – Portage County 2; P3 – Portage County 3; S1 – Stark County 1; S2 – Stark County 2; S3 – Stark County 3; S4 – Start County 4; C1 – Carroll County 1; C2 – Carroll County 2; Co1 – Columbiana County 1; Co2 – Columbiana County 2; C3 – Columbiana County 3; C4 – Columbiana County 4; H1 – Harrison County 1

The Trenton/Lexington structure map shows 12 structural features. The Point Pleasant structure map shows 10 structural features. The Utica structure map shows 14 structural features. These structural features are not strong but are slight “pulls” on the structure contour lines. The structural features across the three formations are all similar in location. Some of the known Precambrian basement faults from Baranoski (2002) and the Silurian and Devonian lineaments from Solis (2016) are comparable in location to the structural features identified. This indicates that these faults and lineaments most likely stem from the Precambrian basement and have been reactivated at least once since the Devonian.

5.3 Isopach Maps

The Trenton/Lexington Limestone is thickest in the center of the study area in a north-south trend. The thickest parts of the study are three localized areas located in central Portage County, eastern Stark, and western Columbiana, and lastly, southern Carroll County, Harrison County, and western Jefferson County (Figure 15). These localized thick areas exceed 90 ft. (27 m). The Trenton/Lexington thins moving east and west of the central portion of the study area. The Trenton/Lexington is thinnest in western Stark County and eastern Columbiana County.

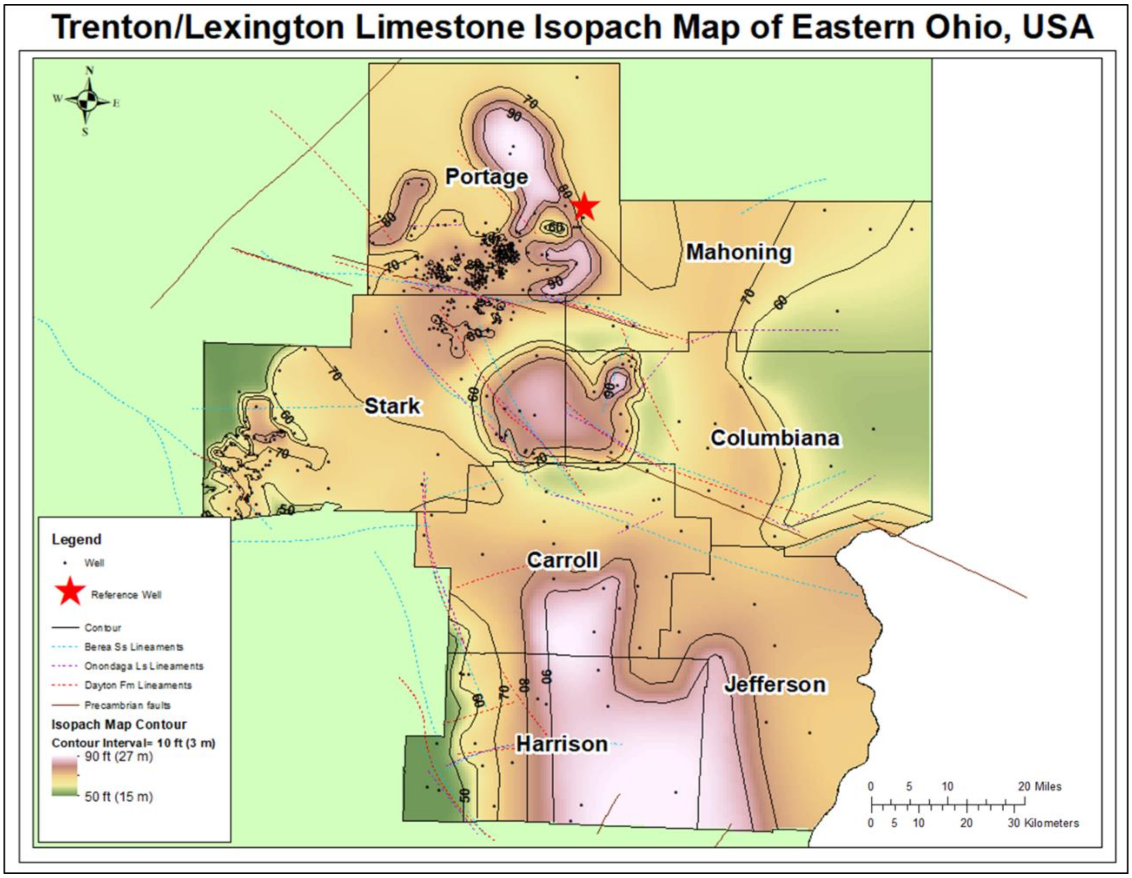

Figure 15. Isopach map of the Trenton/Lexington Limestone. The maps displays thickening and thinning trends of the Trenton/Lexington Limestone in the study area. Faults are from Baranoski (2002) and lineaments are from Solis (2016).

Point Pleasant Formation is thickest in southern Harrison County, Jefferson County, and southeastern Columbiana County (Figure 16). The formation thickens towards the southeast, where the thicknesses exceed 160 ft. (49 m). The Point Pleasant Formation has a northeast-southwest trend of a continuous thickness of 120 ft. to 130 ft. (37 m - 40 m). Point Pleasant is thinnest in the north-northwest portion of Portage County. This portion of Portage County is thinner than 110 ft. (34 m) but has areas thinner than 80 ft. (24 m).

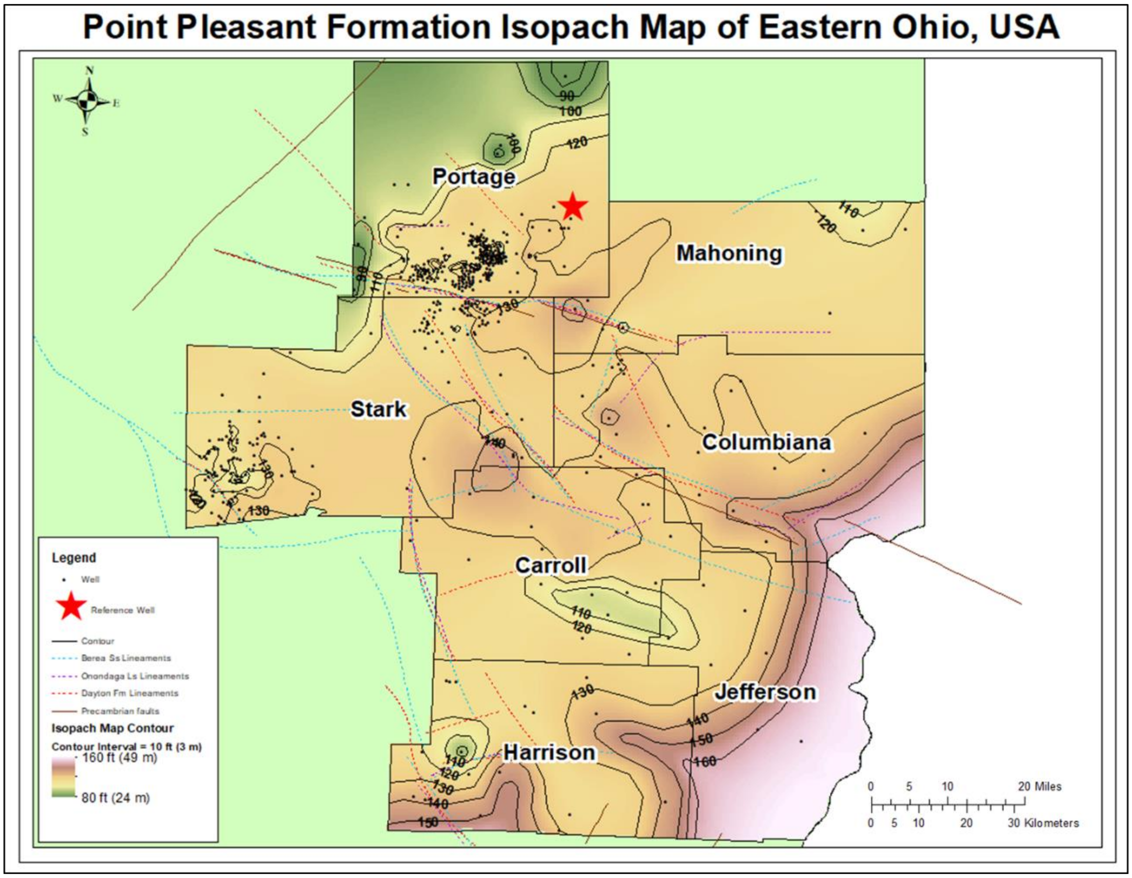

Figure 16. Isopach map of the Point Pleasant Formation. The maps displays thickening and thinning trends of the Point Pleasant Formation in the study area. Faults are from Baranoski (2002) and lineaments are from Solis (2016).

The Utica shale is thickest in northern Portage and Mahoning County (Figure 17). The Utica shale exceeds thicknesses of 210 ft. (64 m). The isopach map displays an east-west trend of continuous thickness ranging from 160 ft. - 170 ft. (49 m- 52m). In northwest Harrison and southwest Carroll counties, there is a high that exceeds 190 ft. (58 m). The Utica shale is thinnest in southern Harrison and eastern Jefferson counties. These areas are thinner than 100 ft. (30 m).

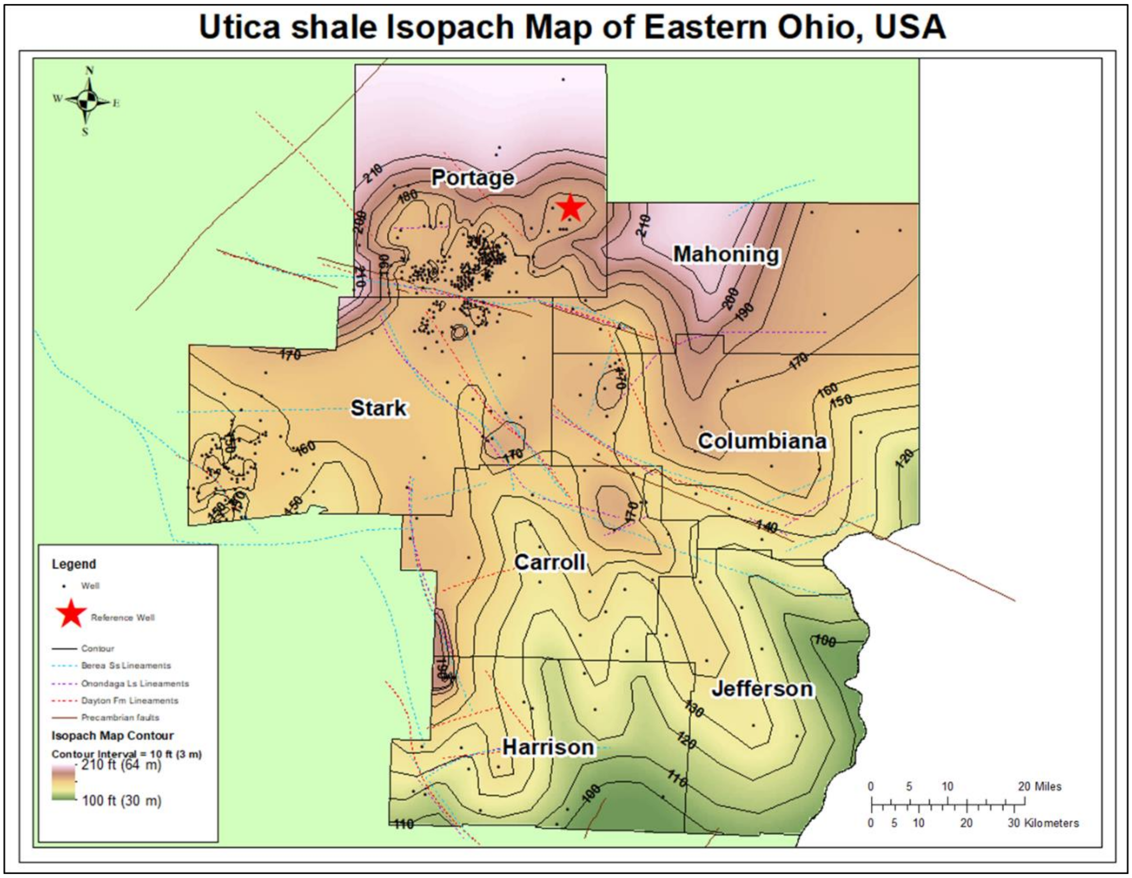

Figure 17. Isopach map of the Utica shale. The maps displays thickening and thinning trends of the Utica shale in the study area. Faults are from Baranoski (2002) and lineaments are from Solis (2016).

6. DISCUSSION

6.1 Structure Maps

The Trenton/Lexington Limestone contains several structural features based on the contours in the structure maps (Figure 12). The fault lines that stem from the Precambrian basement (deeper than the Trenton/Lexington) and the lineaments that were determined to influence strata younger than the Utica shale (shallower than the Utica) are in close proximity to the noted structural features seen in the maps. The noted structural features are most likely faults from the Precambrian basement that have been reactivated at least once since the deposition of the overlying Devonian units, the youngest units that are affected by the faults and lineaments, disrupting modern-day structure slightly based upon the mapping conducted here. Overall, though, the exact timing of the faults cannot be determined simply from the structure maps. Furthermore, definitively stating that these disruptions in the structure are faults, or the amount of offset of these features, is impossible to tell based upon the density of the data in this study.

6.2 Isopach Maps

Trenton/Lexington Limestone isopach map displays a thick carbonate in Harrison, Jefferson, and Carroll counties. This thick carbonate is overlain by thin siliciclastics of the Utica shale in Figure 18. The shape and size of the thick carbonate is similar to the shape and size of the thin siliciclastics deposited on top. The thick carbonate of the Trenton/Lexington Limestone has faults and lineaments running parallel to the thick carbonate on its western side. The eastern side of the thick carbonate does not display any known faults or lineaments running parallel because of the sparse well density in Jefferson County. If well density was high enough, then parallel faults and lineaments would most likely be found on the eastern side of the thick carbonate. This would indicate that the block was faulted and uplifted to create preferential carbonate deposition, causing thickening of the carbonate platform at this location, and limiting siliciclastic deposition.

The cross section of D2-D2' shows a thickening of carbonate over the central portion of the study area in Figure 22. The cross section starts in southwest Portage County and extends through northwest Jefferson County (Figure 19 & 20). The Trenton/Lexington Limestone thickens in the central portion of the study area and thins towards the southeast into Jefferson County. This coincides with isopach maps made of the Trenton/Lexington Limestone that show the thick carbonate bounded on each side by faults and lineaments in the central portion of the study area.

The cross section S2-S2' starts in western Carroll County and extends into north central Mahoning County (Figure 19 & 21). Similar to the D2-D2' cross section, the S2-S2' shows the Trenton/Lexington Limestone thickening in the central portion of the study area where the carbonate thick bounded by faults and lineaments on the Trenton/Lexington Limestone isopach map (Figure 22).

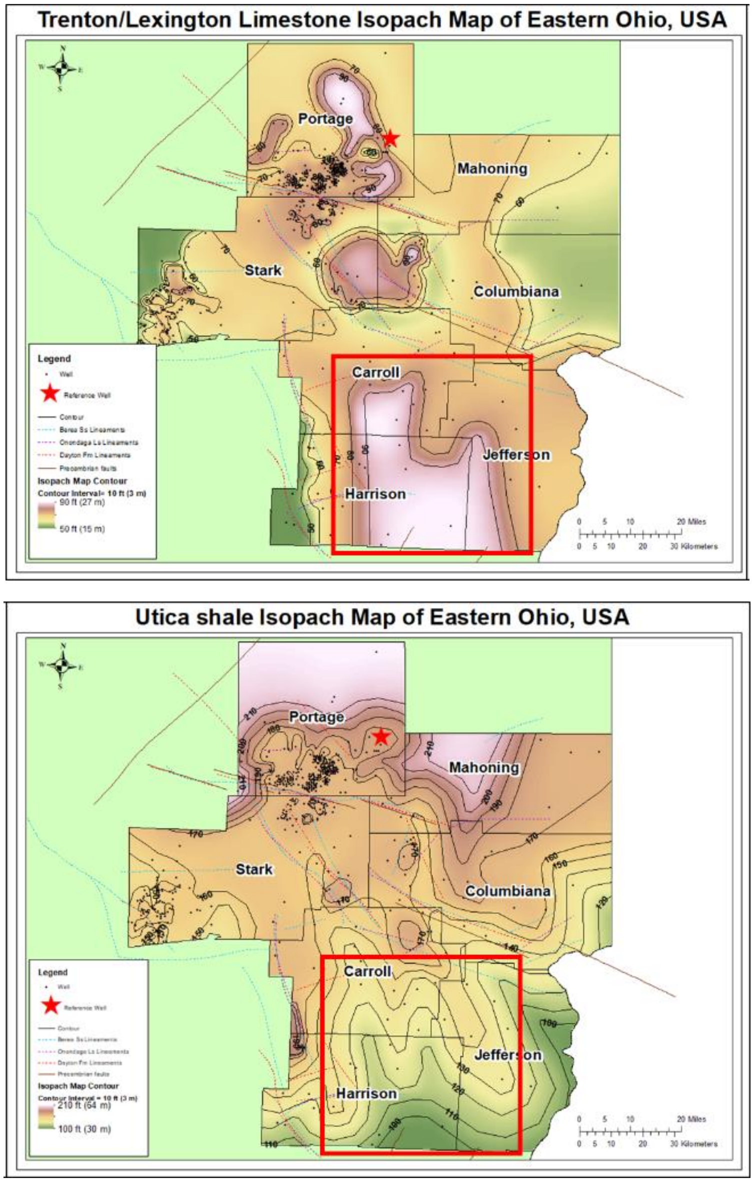

Figure 18. Trenton/Lexington Limestone and Utica shale isopach maps displaying a thick carbonate deposit in southern portion of study area. This carbonate thick is overlain by thin siliciclastics of the Utica shale. The red box indicates area of interest. Faults are from Baranoski (2002) and lineaments are from Solis (2016).

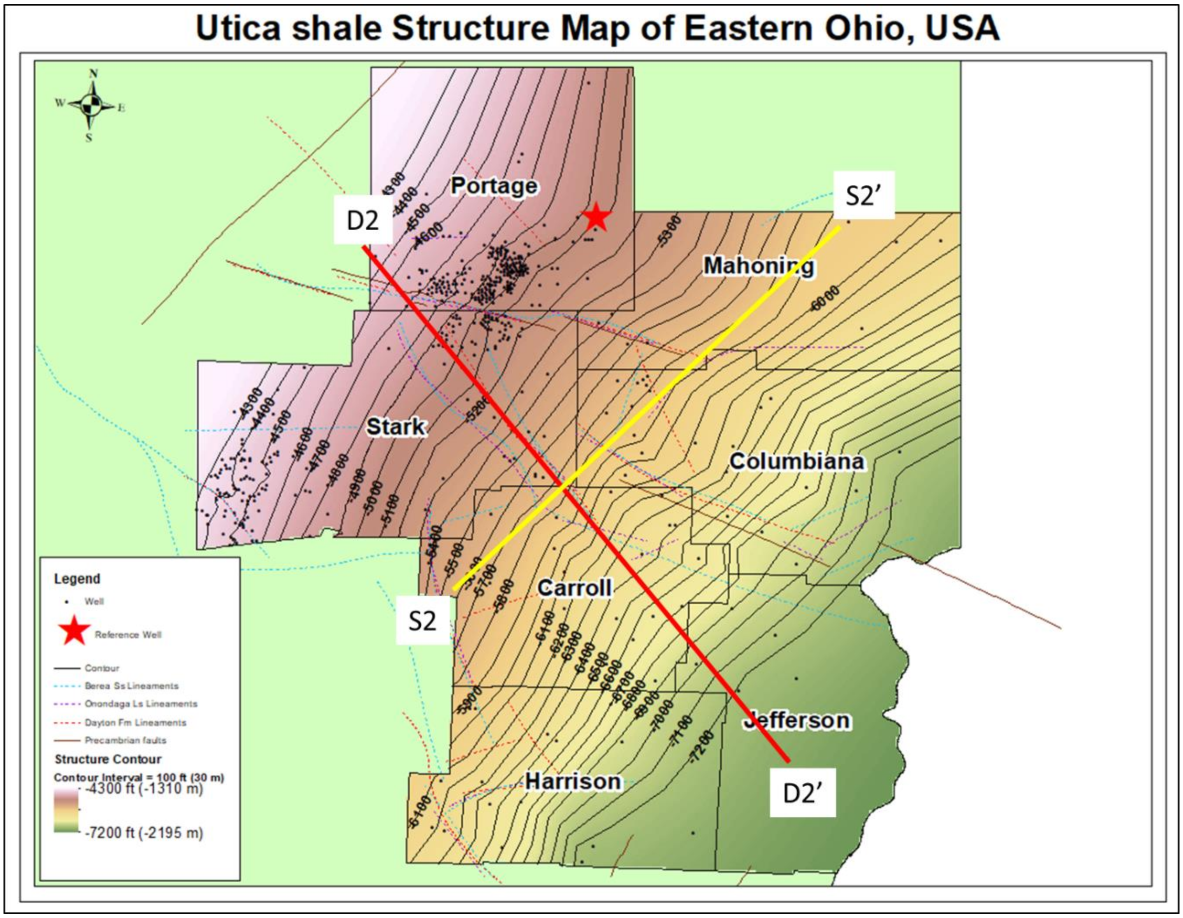

Figure 19. Utica shale structure map displaying two cross section lines within the study area.

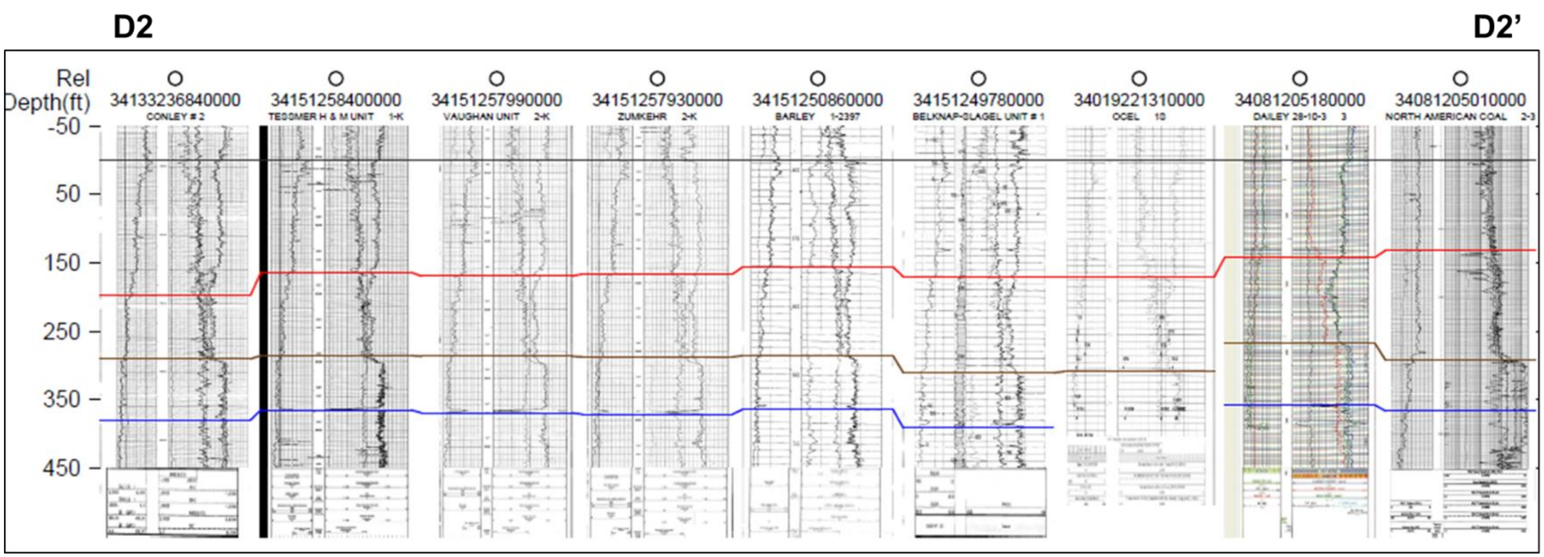

Figure 20. D2-D2’ cross section shown on Figure 19. Black Line= Utica shale; Red Line= Point Pleasant Fm.; Brown line= Trenton/Lexington Limestone; Blue Line= Black River Limestone

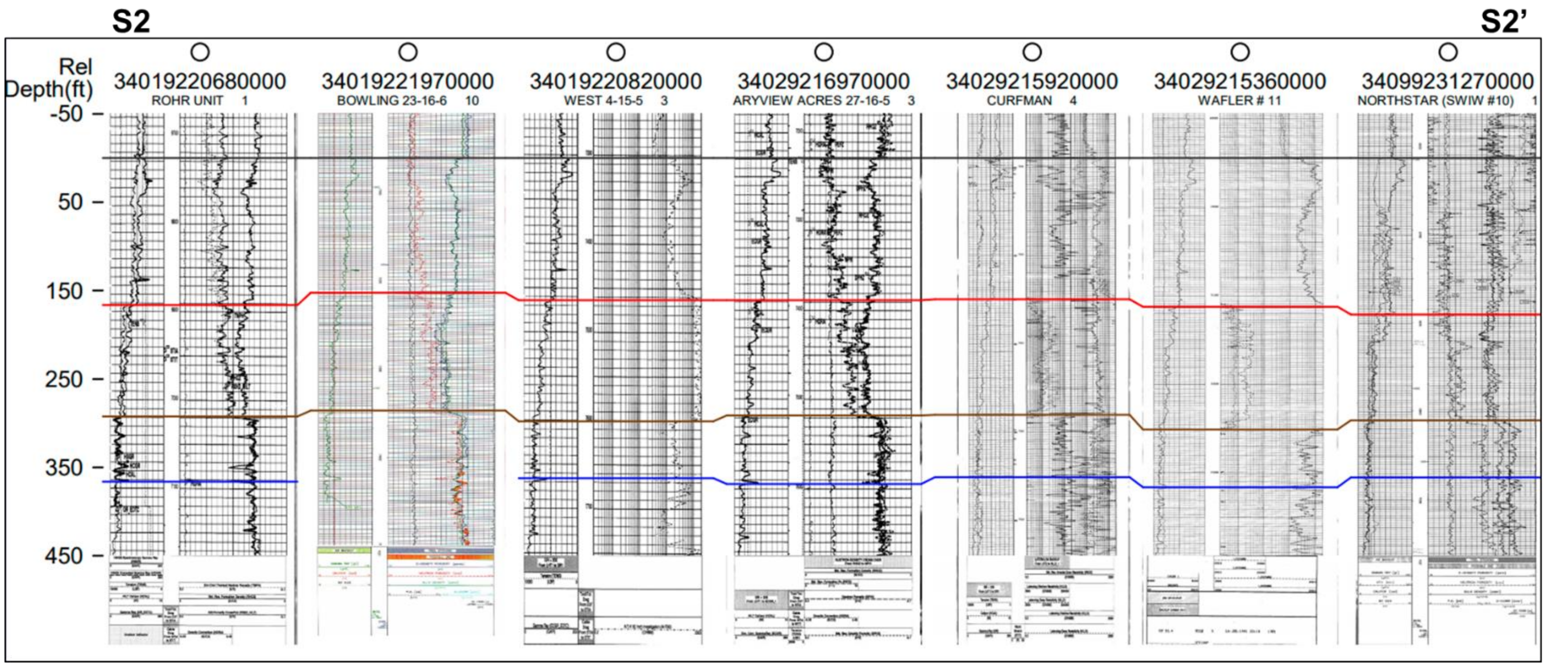

Figure 21. Cross section S2'S2' shown on Figure 19. Black Line= Utica shale; Red Line= Point Pleasant Fm.; Brown line= Trenton/Lexington Limestone; Blue Line= Black River Limestone

Figure 22 shows another example of fault reactivation affecting deposition. In the central portion of the study area, a thick carbonate that is bounded on all sides by faults and lineaments is found. This thick carbonate is overlain by thin siliciclastics of the Point Pleasant Formation and Utica shale. The thin siliciclastics are not abnormally thin, but are thinner than other siliciclastics within the study area. Similar to the process mentioned above for the southern carbonate thick, faulting caused a block of rocks to uplift creating preferential carbonate deposition. This carbonate thick was then overlain by thin siliciclastics.

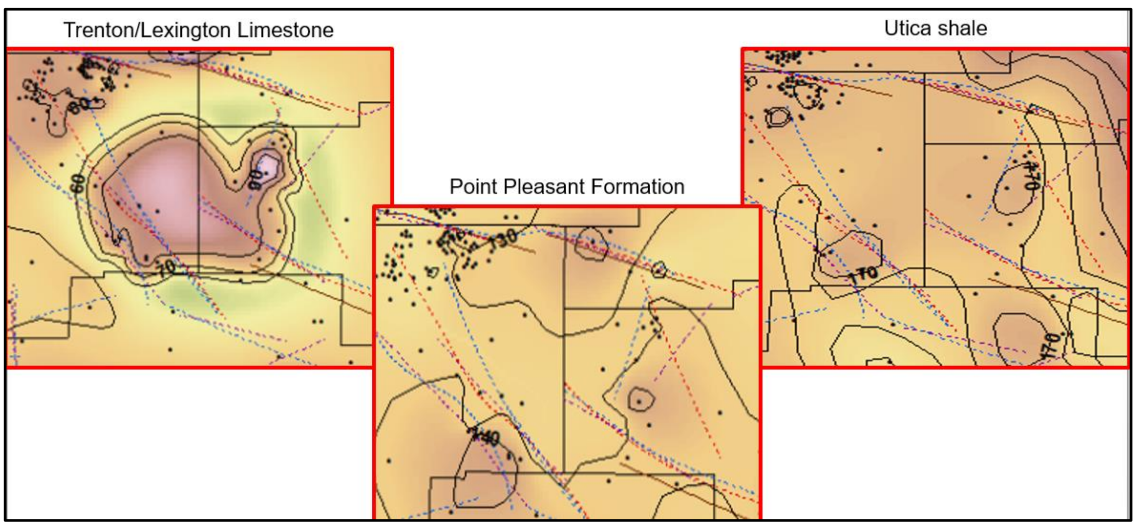

Figure 22. Close up view of the central portion of the study area taken from isopach maps. These maps show a thick Trenton/Lexington Limestone carbonate bounded on all sides by faults (Baranoski, 2002) and lineaments (Solis, 2016). Thinner siliciclastics are deposited on top of carbonate thick. Contour intervals are 10 feet for each map.

During the time of Trenton/Lexington deposition, the carbonate blocks were uplifted either pre- or syn-deposition (Figure 15), creating areas of localized sea level shallowing or deepening. Several of the thickened areas have known faults that flank the sides of the areas of thickened carbonate unit. This uplift created bathymetric highs, allowing for preferential carbonate deposition and areas of thickened Trenton Formation. The Trenton is primarily a packstone to grainstone, consisting of bryozoan, brachiopods, and coral fragments with periodic interbedded shales that occur near the transition to the Point Pleasant Formation. This localized uplifted block would have allowed for increased carbonate deposition while limiting the amount of siliciclastic deposition on the bathymetric highs, and the carbonates would thin on either side of the uplifted block. Furthermore, thinned fine-grained siliciclastic formations overlie several of these areas with thick carbonate deposits. Fine-grained siliciclastic deposition is hindered in shallow marine waters that are above the storm water bed due to the increased energy in the water column, preventing deposition of the clay and silt-sized particles that were shed off of the Appalachian Mountains during the Taconian Orogeny. This suggests that there has been reactivation of faults in Stark, Columbiana, and Portage counties sometime during the Ordovician.

Baranoski (2002) suggests relaxing of Grenville thrust faults east of the Grenville Front Tectonic Zone during the opening of the Iapetus Sea in early Cambrian time established the underpinning structural architecture of the Appalachian Basin. Solis (2016) suggests a history of Cambrian extension followed by compression in their mapping of Silurian and Devonian strata in Belmont and Harrison counties. Patchen et al. (2006) suggest during time of deposition of the Utica shale play that the intensity of the Taconic orogeny increased, creating bulges and down warped areas to create shallow-water platforms and inter-platform sub-basins. Combined with mapping completed by Bloxson (2017), Bridges (2020), and the mapping above, there appears to have been reactivation of faults throughout the Ordovician and subsequent tectonic events in the Appalachian Basin, creating topographic highs and lows that affect sediment deposition. The movement along these faults has had several periods of reactivation. There may be enough offset to properly define the amount of throw and direction if well density is high enough (for example, Mei, 2009); the density in this area can be sparse near the edges. Therefore, more work would be needed.

There are similarities between the Utica shale System and the Wolfcamp Formation in the Permian Basin. The Permian Basin was created by the uplift of the Central Basin Platform and subsidence of the adjacent Delaware and Midland Basins from the thrusting of the Marathon-Ouachita orogenic belt (US EIA, 2018). The mixed siliciclastics from this research are similar to the mixed siliciclastics of the Wolfcamp Formation in the Permian Basin of West Texas (US EIA, 2018). Both Trenton Limestone and Wolfcamp Formation sediments were initially open marine shallow-water carbonate deposits (US EIA, 2018). Due to the subsidence of the Delaware and Midland Basins, siliciclastics were deposited in the sub-basins, similar to Point Pleasant and Utica deposition in the Appalachian Basin (US EIA, 2018). A fault zone along the Central Basin Platform perimeter was active during late Pennsylvanian time (US EIA, 2018). Because of deferential movements of basement blocks, the uplift of the Central Basin Platform created differential subsidence and variable basin geometry in the adjacent Delaware and Midland Basins (US EIA, 2018). This stage of tectonic activity lasted until the end of Wolfcampian time when the fast deformation and subsidence in the sub-basins stopped (US EIA, 2018). The research shows similar faulting and uplift of blocks to create bathymetric highs and lows during deposition of carbonate strata that influenced thick siliciclastic deposits in sub-basins while having thin siliciclastic deposits on the bathymetric highs.

In Northern Portage County and Mahoning County, there is increased thickness in the Utica shale. This increased thickness of the Utica shale appears to be an extension of the Sebree Trough (Figure 23). Kolata et al. (2001) suggest the Sebree Trough evolved from a tectonically induced linear bathymetric depression centered over the Reelfoot Rift during latest Turinian to early Chatfieldian time, coinciding with the latest Turinian and early Chatfieldian sea-level rise recorded in the Midcontinent (Kolata et al., 2001). This preexisting depression, which extended from the cratonic margin in Arkansas to southern Illinois, apparently descended into deeper, cooler, oxygen-poor, phosphate-rich waters entering from the Iapetus Ocean (Kolata et al., 2001). Differentiation of the Sebree Trough was marked by the cessation of carbonate sedimentation, corrosion of carbonate substrate, deposition of graptolitic shales, development of hardground omission surfaces, and local phosphogenesis (Kolata et al., 2001). The coeval upward growth of the carbonate platforms to the northwest and southeast sustained and enhanced the development of the trough (Kolata et al., 2001). Where preexisting bathy-metric depressions are present (e.g., Sebree Trough–Reelfoot Rift), platform drowning can be rapid and can extend far within platforms, away from obvious sources of eutrophic waters (Kolata et al., 2001). This research shows an increased thickness of Utica shale in northern Portage County and Mahoning County, with areas of thin carbonate platform underneath. While previous research does not support that the Sebree Trough extends into eastern Ohio, new research has shown thickening of fine-grained sedimentary rocks and thinning carbonates underneath (Bloxson, 2017; Bridges, 2020). The study area here is located at what is thought to be the southern edge of the

Sebree Trough in northeast Ohio, and shows thickening in the northern section of the study area.

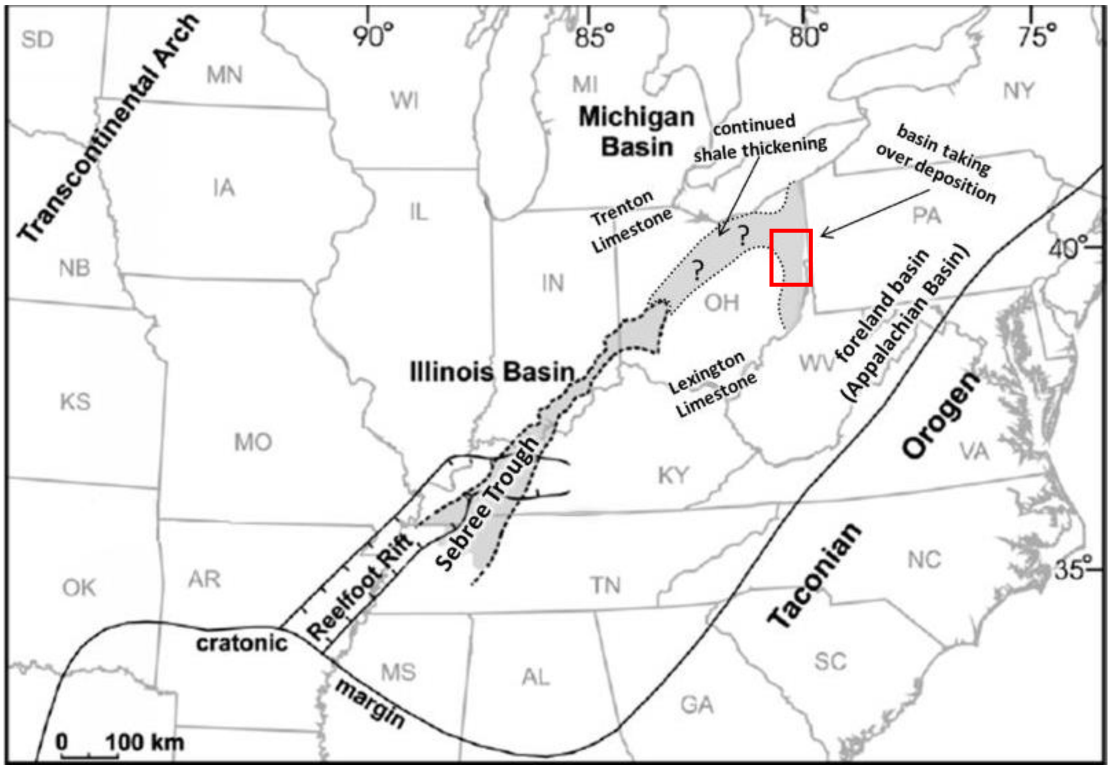

Figure 23. Eastern United States showing the extent of the Sebree Trough from Tennessee, through Kentucky, Indiana and southwest Ohio taken from Bloxson (2017). Modern research has provided evidence for the extension of the Sebree Trough into northeast Ohio. Red box designates the study area.

7. CONCLUSIONS

The Utica shale play of eastern Ohio is a major oil and gas producing interval throughout the Appalachian Basin. The Utica shale play has a similar northwest-southeast trending dip but has localized structural anomalies throughout. The Trenton/Lexington Limestone has possible faulting and/or lineaments throughout the seven-county study area that occurred either pre- or syn-depositional and post-deposition as well. The Trenton/Lexington Limestone is thicker in the north, central and southern portion of the study area and thins towards the east and westward from the center of the study area. The Point Pleasant Formation has similar structural attributes as the Trenton/Lexington Limestone throughout the study area. The Point Pleasant mixed carbonates and siliciclastics are thickest in Harrison, Jefferson, and Columbiana counties and thin towards the northwest in Portage and Stark counties. The thickest portion of the Utica shale is in northern Portage and Mahoning counties and thins towards Harrison and Jefferson counties in the south.

The isopach maps show carbonates are thickest in Harrison and Jefferson counties and are thinner in Portage, Stark, and Mahoning counties in the north. Siliciclastics are thicker in Portage, Stark, and Mahoning counties and are thinner in Harrison and Jefferson counties. This suggests that there was a localized bathymetric low for the carbonates to deposit during the Trenton/Lexington time. During the Point Pleasant time, the siliciclastics began to thin towards Portage and Mahoning counties, where the water depth increased but remained shallow in Harrison and Jefferson counties. The siliciclastics then increased in thickness by the Utica shale time in Portage, Stark, and Mahoning counties' overlying mixed siliciclastics of the Point Pleasant. To the south in Harrison and Jefferson counties, siliciclastics overlie the thicker, mostly siliciclastics, of the Point Pleasant.

Previous workers have suggested multiple episodes of reactivation of faults throughout the Appalachian Basin (Baranoski, 2002; Solis, 2016; Patchen et al., 2006). The carbonates during the Trenton/Lexington time appear to have been building reef systems on areas of topographic high's, potentially flanked by reactivated faults. Then during the Utica/Point Pleasant time, further reactivation of faults could have relaxed areas for deeper water and increased deposition of siliciclastics in Portage, Stark, and Mahoning counties and leaving thicker carbonates and thinner siliciclastics in Harrison and Jefferson counties.

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9. APPENDICES

Appendix 1 – Utica shale play wells used in the study. API, Well Name and Formation Boundary information in feet below sea level. PP=Point Pleasant; T/L=Trenton/Lexington.

UWI/API	WELLNAME	COUNTY	UTICA	PP	T/L
34019221970000	BOWLING 23-16-6 10	CARROLL	-5823	-5976	-6109
34019226890000	PERRY UNIT 2S	CARROLL			0
34019220820000	WEST 4-15-5 3	CARROLL	-6055	-6216	-6352
34019221310000	OCEL 1S	CARROLL	-6379	-6549	-6687
34019219200000	HICKORY CLAY 12	CARROLL	-5385	-5547	-5672
34019221960000	KOVACH 3-15-6 1	CARROLL			0
34019220500000	ROBERTSON W & J UNIT 1	CARROLL	-5556	-5716	-5855
34019220810000	SHAW 20-14-5 5H	CARROLL	-6299	-6447	-6579
34019220840000	CONIGLIO 7-14-4 6	CARROLL			0
34019220890000	BAILEY 35-12-4 6	CARROLL	-6668	-6800	-6919
34019220680000	ROHR UNIT 1	CARROLL	-5736	-5902	-6028
34019222120000	KRUPRZAK 17-13-4 3	CARROLL	-6576	-6726	-6853
34019220900000	TANNER 24-12-4 10	CARROLL			0
34019221390000	P BROWN 9-13-5 1	CARROLL			0
34019221190000	SCOTT 24-12-5 3	CARROLL			0
34019221380000	TUCKOSH 35-11-4 1	CARROLL	-6883	-7009	-7134
34019220450000		CARROLL	-5464	-5626	-5755
34019220530000	MILLER 1	CARROLL	-6190	-6325	-6443
34019218770000	TOALSTON UNIT 1	CARROLL	-6339	-6501	-6626
34019218500000	BRYAN UNIT 1	CARROLL	-6416	-6562	-6689
34019220590000	WHITE 1	CARROLL	-6460	-6606	-6713
34029216940000	SANOR FARMS 23-17-5 3	COLUMBIANA	-5800	-5972	-6102
34029216970000	ARYVIEW ACRES 27-16-5 3	COLUMBIANA	-6021	-6181	-6312
34029218040000	ALTENHOF 10-15-4 3	COLUMBIANA			0
34029217190000	TREBILCOCK 25-15-4 1	COLUMBIANA			0
34029215930000	HEROLD 2-A	COLUMBIANA	-5765	-5933	-6069
34029215980000	SCHOENI NOB: GROSS2-A	COLUMBIANA		-5920	-6047
34029217050000	ALBANESO 24-14-4 8	COLUMBIANA			0
34029216020000	DENNY/STANLEY 1	COLUMBIANA	-5744	-5909	-6033
34029214750000	MULINIX ET AL # 1	COLUMBIANA			0

34029215210000	BLICKENSDERFER # 5	COLUMBIANA		-5869	-5994
34029215360000	WAFLER # 11	COLUMBIANA	-5806	-5975	-6113
34029215670000	DONALD L. DENNY # 2	COLUMBIANA	-5763	-5933	-6059
34029217060000	JANIE TRUST 5-12-3 1	COLUMBIANA	-6988	-7126	-7260
34029215910000	WOOLF W J WELL 3	COLUMBIANA	-5865	-6034	-6181
34029217240000	KERNICH 3-10-2 1	COLUMBIANA	-7045	-7205	-7342
34029216220000	ENTRIKIN UNIT 1	COLUMBIANA	-6323	-6494	-6624
34029215920000	CURFMAN 4	COLUMBIANA	-5973	-6133	-6263
34029216190000	F-P-S-M YOUNG 1	COLUMBIANA	-6332	-6502	-6637
34029217270000	CARNEY 17-7-1 3	COLUMBIANA	-7115	-7252	-7390
34029216040000	ALLIANCE/SEI UNIT 1	COLUMBIANA	-6287	-6465	-6591
34029216370000	SOWARDS UNIT 1-K	COLUMBIANA	-6779	-6946	-7078
34029214760000		COLUMBIANA	-6820	-6962	-7104
34067212350000	E CLARK SOUTH # 7	HARRISON			0
34067210650000	BOY SCOUT 1-33	HARRISON	-6465	-6590	-6711
34067210630000	STUART HENDERSON 11-12-6 3	HARRISON			0
34067210790000	GOTSHALL 14-12-5 3	HARRISON			0
34067209710000	PATTERSON ORVILLE 3	HARRISON	-5954	-6151	-6272
34067209430000	STEWART UNIT 5	HARRISON			0
34067210820000	CNXHAR10N5W 1P-23	HARRISON			0
34067207650000	G. BARRICKLOW # 1	HARRISON	-5928	-6107	-6233
34067209720000	PATTERSON ORVILLE 2	HARRISON	-5978	-6133	-6344
34067210620000	WAGNER 1	HARRISON	-7226	-7329	-7459
34067210570000	NORTH AMERICAN COAL ROYALTY CO BUELL	HARRISON	-6912	-7037	-7173
34067207640000	CLYDE VAN HORN # 1	HARRISON	-6291	-6422	-6518
34067205910000	B. BERRY # 1	HARRISON			0
34067208600000	PERKOWSKI-BOND # 2	HARRISON	-6226	-6345	-6483
34067207770000	D C JONES 7	HARRISON	-6601	-6743	-6886
34067211280000	CNXHAR 9N4W 1P-7A	HARRISON			0
34067207370000	ZECHMAN THOMAS # 1	HARRISON			0
34067210740000	CNXHAR9N5W 1P-24	HARRISON			0
34081205120000	VAHALIK 18-11-4 8	JEFFERSON			0
34081205070000	BROWN 36-11-3 10	JEFFERSON			0
34081205180000	DAILEY 28-10-3 3	JEFFERSON	-7206	-7347	-7474
34081205080000	ASUNCION WEST 15-11-3 3	JEFFERSON			0
34081205130000	DENOON 5-10-3 3	JEFFERSON			0
34081205010000	NORTH AMERICAN COAL 2-3	JEFFERSON			0
34081205280000	NAC 3P-20	JEFFERSON			0
34099228440000	BUCHS I & N 1-12 535	MAHONING	-5359	-5520	-5667
34099227640000	HAHLEN UNIT 3	MAHONING			0
34099202120000	BRENNER 1	MAHONING	-5401	-5574	-5710
34099227490000	COURTNEY UNIT # 5	MAHONING	-5633	-5792	-5910
34099231270000	NORTHSTAR (SWIW #10) 1	MAHONING	-5936	-6113	-6232

34099231570000	NORTHSTAR KHALIL (SWIW #11) 3	MAHONING	-6004	-6179	-6294
34099231710000	NORTHSTAR COLLINS (SWIW #13) 6	MAHONING	-6136	-6313	-6436
34099231580000	NORTHSTAR LUCKY (SWIW #12) 4	MAHONING	-6277	-6451	-6573
34133242600000	KOST 3-C	PORTAGE			0
34133244300000	ASHER PORT2AHSU	PORTAGE	-4691	-4853	-4978
34133244200000	HOSEY POR 6H-X	PORTAGE			0
34133244230000	MURVAY POR 8	PORTAGE			0
34133240460000	SIMON UNIT # 2	PORTAGE			-4788
34133238440000	WOODWARD # 1	PORTAGE			-4771
34133240400000	CAROLYN-KENT # 1	PORTAGE			-4829
34133236840000	CONLEY # 2	PORTAGE	-4459	-4657	-4749
34133240270000	WANTZ R UNIT # 1-2161	PORTAGE		-4836	-4913
34133240220000	KLEIN P & J COMM #1 # 8158-001	PORTAGE	-4607	-4773	-4897
34133238970000	BOYER # 1	PORTAGE			0
34133238100000	SCHAEFER # 1	PORTAGE			-5036
34133239620000	K & F VASHBINDER COMM. #1 # 3555-001	PORTAGE	-4673	-4838	-4958
34133244040000	M & L WOHLWEND 1-KA	PORTAGE	-4676	-4842	-4967
34133239270000	KISAMORE # 1	PORTAGE			-4966
34133244270000	EVANS W & C 2-K	PORTAGE	-4663	-4849	-4958
34133239280000	KISSEL # 2	PORTAGE			-5007
34133239710000	SCHAEFER # 2	PORTAGE			-5024
34133244130000	EVANS UNIT 1-K	PORTAGE			0
34133239630000	PETERSON # 1	PORTAGE	-4714	-4887	-5010
34133237140000	KINSEY UNIT # 1	PORTAGE	-4594	-4813	-4900
34133239150000	M & M STEFFEE COMM #1 # 3470-001	PORTAGE	-4656	-4822	-4942
34133240000000	PERO # 1	PORTAGE			-5052
34133244670000	K & W EVANS 4-K	PORTAGE			-4972
34133244080000	MAY 1-K	PORTAGE			0
34133239650000	HUDACSEK # 1	PORTAGE	-4723	-4885	-5014
34133239940000	LINDEMAN # 1	PORTAGE			-5101
34133239380000	C & R STEPHENS COMM 1-3483	PORTAGE	-4749	-4922	-5040
34133237780000	CONNOR C COMM 1	PORTAGE	-4818	-4988	-5115
34133239520000	R & C LOREE COMM 3491-001	PORTAGE	-4768	-4933	-5055
34133238400000	D. & F. CUNNINGHAM COMM. #1 # 3437-001	PORTAGE	-4747	-4907	-5040
34133239730000	LAUBURT # 1	PORTAGE			-5095
34133240280000	HYDE P P COMM 1 # 8473-001	PORTAGE	-4780	-4946	-5069
34133239530000	WISE D & L COMM 3496-01	PORTAGE	-4752	-4918	-5039
34133239450000	BOOHER # 1	PORTAGE			-5067
34133239460000	W. HANKEY ETAL COMM. #2 # 4384-001	PORTAGE	-4810	-4979	-5099
34133203360000	ALVIN ROTHERMEL COMM #1D # 388-001	PORTAGE	-4769	-4933	-5060
34133239220000	J. HOUCK COMM.#1 # 3471-001	PORTAGE	-4789	-4960	-5082
34133238750000	OLIVER # 1	PORTAGE			-5145
34133238880000	W.R. TRUOG # 2-1564	PORTAGE	-4744	-4961	-5049

34133239420000	BAILEY # 1	PORTAGE			-5058
34133239370000	WISE # 1	PORTAGE	-4776	-4934	-5067
34133238610000	V PLOSKUNAK COMM 1	PORTAGE	-4801	-4967	-5090
34133239470000	WISE UNIT 2	PORTAGE			-5028
34133238090000	KLINE # 1	PORTAGE			-4906
34133239670000	CLINTON PETROLEUM COMM #2 # 3557-001	PORTAGE	-4797	-4981	-5097
34133239860000	BORDENKIRCHER # 1	PORTAGE			-5060
34133239760000	KIDIKAS # 1	PORTAGE			-5131
34133239680000	W. WISE # 1	PORTAGE	-4770	-4939	-5059
34133239430000	ST JOSEPH 1	PORTAGE	-4729	-4892	-5021
34133239750000	CLIFFORD UNIT # 3-1851	PORTAGE	-4712	-4881	-4999
34133239510000	JAMES & SHIRLEY HOUSE 3	PORTAGE	-4736	-4905	-5027
34133238260000	OFM CO COMM 1	PORTAGE	-4830	-4988	-5117
34133239080000	W. MCGRATH ETAL COMM.#1 # 3469-001	PORTAGE	-4816	-4982	-5105
34133240660000	WINNEFELD # 1-2253	PORTAGE	-4667	-4838	-4964
34133239490000	R WARD COMM #1 # 3485-001	PORTAGE	-4756	-4924	-5049
34133237940000	R &E ARTIM COMM 1	PORTAGE	-4806	-4979	-5109
34133240320000	SIEGFERTH J & E COMM #1 # 8488-001	PORTAGE	-4831	-4999	-5118
34133237770000	BOOHER # 2A	PORTAGE	-4765	-4932	-5060
34133241250000	RICE RR1	PORTAGE			0
34133241760000	KERR 1	PORTAGE			-5188
34133241650000	BLACKMAN 1	PORTAGE	-4864	-5029	-5151
34133238910000	A. KNECHT ETAL COMM. #2 # 3448-001	PORTAGE	-4862	-5029	-5163
34133241630000	BOOHER 1	PORTAGE	-4798	-4965	-5087
34133241790000	METZNER 4	PORTAGE			-5168
34133240240000	BROCKETT # 5	PORTAGE			-5221
34133241480000	TYMCIO 1	PORTAGE			-5161
34133241670000	RICE 3	PORTAGE			-5207
34133241770000	FLOWERS 1	PORTAGE	-4857	-5026	-5150
34133239180000	RUDD # 1	PORTAGE			-5240
34133241490000	METZNER 1	PORTAGE	-4906	-5076	-5216
34133240190000	F. & G. RODENBUCHER COMM. #1 # 3835-001	PORTAGE	-4920	-5088	-5208
34133241500000	METZNER 2	PORTAGE			-5177
34133241300000	DARRAH 2	PORTAGE			0
34133241820000	BRADLEY 3	PORTAGE			0
34133241660000	RICE 2	PORTAGE			0
34133241840000	RIPLEY UNIT 1	PORTAGE	-4817	-4990	-5116
34133241610000	NEWHART-MILLER UNIT 4	PORTAGE			-5201
34133241620000	NEWHART-MILLER UNIT 6	PORTAGE	-4937	-5106	-5231
34133241560000	WOLFF B UNIT 1-2383	PORTAGE	-4883	-5056	-5173
34133241550000	KENNEDY 2-2368	PORTAGE	-4916	-5083	-5204
34133241830000	FLOWERS 2	PORTAGE	-4875	-5046	-5175
34133242120000	TIMMS 1	PORTAGE			-5234

34133239810000	HORNING # 1	PORTAGE			-5184
34133239820000	C & P WISE COMM 1	PORTAGE			0
34133240130000	DUNKLE # 1	PORTAGE			0
34133241870000	SNYDER S COMM 1	PORTAGE	-4874	-5033	-5164
34133240650000	HILL W & A ETAL COMMUNITY # 1-8838	PORTAGE	-4900	-5074	-5197
34133241070000	BRANNON D W 1	PORTAGE			-5205
34133238790000	R. & K. HILGERT #1 # 3447-001	PORTAGE	-4749	-4920	-5040
34133240090000	J. E. & S. M. DAVIS COMM. #1 # 3690-001	PORTAGE	-4941	-5107	-5234
34133240120000	TIRE TREAD DEVELOPMENT COMM. #1 # 3691-0	PORTAGE	-4926	-5095	-5219
34133240330000	FOX W COMM #2 # 8489-001	PORTAGE	-4909	-5081	-5202
34133240390000	RICHARDS # 2	PORTAGE			0
34133241690000	SMITH D 6	PORTAGE			-5159
34133240230000	BROCKETT # 4	PORTAGE			-5228
34133239850000	HALL # 1	PORTAGE			-5158
34133239830000	D & R D'AGOSTINE COMM #1 # 3562-001	PORTAGE	-4928	-5095	-5218
34133240180000	MILLER # 1	PORTAGE			-5192
34133241430000	HERBRUCK #2-K	PORTAGE			-5264
34133240160000	MANHOLT UNIT 3	PORTAGE			-5202
34133242490000	PUGH 3	PORTAGE			-5249
34133240370000	CAHILL # 1	PORTAGE			-5250
34133241850000	SNYDER S COMM #2 12231-001-00	PORTAGE	-4893	-5056	-5193
34133239720000	FRITZ # 1-A	PORTAGE	-4959	-5134	-5264
34133240790000	WISE # 2-RR	PORTAGE			-5284
34133241340000	MINEAR UNIT 2	PORTAGE	-4943	-5113	-5236
34133240170000	STOTLER 1	PORTAGE			-5227
34133240580000	BOWMAN 2	PORTAGE			-5245
34133240740000	PAMER UNIT 3	PORTAGE			-5247
34133240430000	RICHARDS UNIT 2	PORTAGE			-5248
34133241570000	KIRKLAND M & A COMM 1	PORTAGE	-4933	-5100	-5222
34133241450000	FREEMAN UNIT #2-K	PORTAGE			-5277
34133240410000	PAMER # 2	PORTAGE			-5252
34133241590000	KOST T & M 1-RR	PORTAGE			0
34133241090000	M. SMITH #1 12119-01	PORTAGE	-4995	-5159	-5277
34133239870000	T & M MCGUIRE COMM. #1 # 3563-001	PORTAGE	-4914	-5082	-5208
34133240250000	MEREDITH # 3	PORTAGE			-5223
34133241130000	MCKNIGHT # 2-RR	PORTAGE			-5285
34133239950000	R & L SLAUGHTER COMM. #1 # 3687-001	PORTAGE	-4922	-5086	-5210
34133240480000	CORL UNIT # 1-2227	PORTAGE			-5262
34133240550000	MCGUIRE T & M # 2-11845	PORTAGE	-4905	-5074	-5198
34133240890000	CRAMNER # 4-2304	PORTAGE	-4982	-5151	-5277
34133240140000	ACORD UNIT # 1	PORTAGE			-5182
34133240150000	WALLBROWN # 2	PORTAGE			-5257
34133242410000	PUGH 2	PORTAGE			-5276
34133240560000	COGAN S COMMUNITY # 11846-1	PORTAGE	-4936	-5108	-5228

34133242450000	GODFREY UNIT 1-RR	PORTAGE			-5324
34133240990000	GROSSENBACHER UNIT 1	PORTAGE			-5231
34133240980000	ZAVARA-KIBLER UNIT 2	PORTAGE			-5287
34133241780000	METZNER 3	PORTAGE			-5152
34133240600000	EBIE # 4	PORTAGE			-5260
34133241080000	DUMONT P & R COMMUNITY #1 12114-001-	PORTAGE	-4967	-5133	-5248
34133242430000	JONES 1	PORTAGE		-5150	-5256
34133241240000	REED # RR1	PORTAGE			0
34133240040000	WALLBROWN 4	PORTAGE			-5251
34133243870000	LOCKHART UNIT 1	PORTAGE	-4903	-5073	-5200
34133238410000	A. & S. SCRUGGS COMM. #1 # 3438-001	PORTAGE	-4824	-4990	-5113
34133241520000	PUGH UNIT 1	PORTAGE			-5256
34133242660000	KILGORE 1	PORTAGE			0
34133241800000	JACKSON 1	PORTAGE	-4907	-5088	-5208
34133242310000	DEERFIELD FARMS 5	PORTAGE			-5322
34133236120000	MEREDITH UNIT # 1	PORTAGE			-5236
34133240340000	PLYMALE UNIT 1	PORTAGE			-5312
34133241350000	SMITH D 5	PORTAGE		-5054	-5173
34133242210000	BAUMAN P 15	PORTAGE	-4916	-5096	-5219
34133241860000	SNYDER W & S 1	PORTAGE	-4909	-5069	-5200
34133240500000	SPELLMAN JAMES A & ALICE M # 11844	PORTAGE	-4958	-5123	-5251
34133240640000	EBIE # 5	PORTAGE			-5256
34133240670000	WISE UNIT # 2-A	PORTAGE			-5280
34133240610000	WISE UNIT # 1	PORTAGE			-5283
34133241120000	MOLEDOR-RAFFERTY 2	PORTAGE		-5122	-5254
34133241040000	LEIENDECKER R & J 1	PORTAGE	-4942	-5121	-5237
34133241600000	NEWHART-MILLER UNIT 5	PORTAGE	-4939	-5111	-5237
34133242520000	ABBE 4	PORTAGE			-5326
34133241740000	GEIB G & D COMMUNITY 1	PORTAGE	-4947	-5110	-5233
34133242810000	FINNEGAN 4	PORTAGE		-5166	-5289
34133240590000	WALKER UNIT # 2	PORTAGE			-5261
34133242250000	ANDERSON 1	PORTAGE			-5292
34133239910000	KOLASKY # 1	PORTAGE			-5183
34133240730000	GAY # 2	PORTAGE			-5379
34133240490000	BARNETT # 2 K-W	PORTAGE			-5260
34133239580000	DANKO # 1	PORTAGE			-5230
34133241200000	KOST T ETAL # 2	PORTAGE			-5285
34133244640000	SMITH W & N 4-K	PORTAGE	-5024	-5200	-5325
34133240900000	CRAMNER # 3-2303	PORTAGE	-4965	-5138	-5264
34133239800000	MCKAY # 1	PORTAGE			-5213
34133240210000	STRADER J & S COMM #1 # 7770-001	PORTAGE	-4920	-5088	-5208
34133242330000	WISE H & O 3	PORTAGE			-5322
34133239030000	C. & M. BINGHAM COMM. #1 # 3459-001	PORTAGE	-4784	-4949	-5072

34133239780000	BAILEY-DAVIS # 2-1565	PORTAGE			-5244
34133241810000	WASS P-7	PORTAGE	-4997	-5184	-5318
34133242350000	DEMYAN 2	PORTAGE			-5323
34133242020000	WILKERSON 1	PORTAGE			0
34133240720000	EBIE 6	PORTAGE			-5268
34133240030000	WALLBROWN # 3	PORTAGE			-5249
34133241140000	MASSA F & C 1	PORTAGE			-5269
34133242750000	ENGLEHART 2	PORTAGE			-5311
34133240940000	AMLIN UNIT 1	PORTAGE			0
34133242500000	SCHULTZ LAKE UNIT 1	PORTAGE			-5327
34133242510000	FINEGAN UNIT 2	PORTAGE			-5301
34133239790000	DANKO # 2	PORTAGE			-5218
34133241150000	REESE UNIT # 1	PORTAGE			-5263
34133240920000	DORNAN 2	PORTAGE			-5291
34133241110000	DEERFIELD LANDS 1-2342	PORTAGE			-5272
34133241160000	DORNAN # 1	PORTAGE			-5295
34133241290000	H & O WISE #2	PORTAGE			-5287
34133239840000	DANKO # 3	PORTAGE			-5231
34133239920000	HOLLENDONNER 1	PORTAGE			-5241
34133240800000	WISE UNIT # 3	PORTAGE			-5289
34133241710000	SANDERS UNIT 2-K	PORTAGE			-5411
34133241970000	DEMYAN 1	PORTAGE			-5288
34133242300000	KOST 2	PORTAGE			0
34133242400000	ABBE UNIT 2	PORTAGE			-5296
34133242440000	MOFF UNIT 2-K	PORTAGE			0
34133239590000	KEMPH # 2	PORTAGE			-5309
34133238730000	GEIGER # 1	PORTAGE			-5067
34133240860000	GAY # 3	PORTAGE			0
34133241020000	RICHARDS W ET AL COMM #1 12086-001-	PORTAGE	-4958	-5134	-5250
34133242000000	DEERFIELD FARMS RR 1-A	PORTAGE			-5302
34133240700000	MCBROOM UNIT 1	PORTAGE			-5261
34133241310000	RYAN UNIT 1	PORTAGE			-5283
34133242090000	SHEWELL UNIT P-11	PORTAGE	-4953	-5124	-5246
34133242140000	DEERFIELD FARMS R.R. 3	PORTAGE			-5316
34133240100000	KINSEY 1	PORTAGE			-5268
34133242390000	EDWARDS 1	PORTAGE			-5346
34133240850000	WISE # 1	PORTAGE			-5309
34133242070000	PITTMAN 2	PORTAGE			-5307
34133242150000	DEERFIELD FARMS RR 4	PORTAGE			-5322
34133242320000	GRAHAM 1 RR	PORTAGE			0
34133240810000	CRAIN UNIT # 2K-W	PORTAGE			-5275
34133241720000	PORTAGE-BURKEY UNIT #2-K	PORTAGE			-5304
34133242220000	DEERFIELD FARMS R.R. 2	PORTAGE			0

34133242280000	HORN 1	PORTAGE			0
34133240200000	JENKINS # 1	PORTAGE			-5214
34133243040000	ABBE 5	PORTAGE			-5352
34133239960000	BURKHEAD # 1	PORTAGE			-5273
34133241940000	LANTZ 2-K	PORTAGE			-5455
34133242200000	EHASZ P14	PORTAGE	-4952	-5126	-5247
34133244510000	RUGGLES 3-K	PORTAGE	-5086	-5260	-5394
34133240840000	WOODS UNIT # 2	PORTAGE	-5079	-5251	-5374
34133241930000	KAINRAD P-8	PORTAGE	-5109	-5282	-5412
34133242760000	MYERS G & L UNIT 1-RR	PORTAGE			-5409
34133240420000	SCOTT HEIRS UNIT #2	PORTAGE	-5106	-5276	-5419
34133244070000	PANDER UNIT 1	PORTAGE	-5128	-5300	-5427
34133242680000	SCOTT HEIRS 3	PORTAGE	-5108	-5289	-5417
34133239890000	DITTMER # 2	PORTAGE			-5443
34133240870000	KARAS # 16	PORTAGE			-5466
34133240820000	VENCE-HAISS UNIT # 2	PORTAGE			-5463
34133228600000	VIKING RESOURCES CORP. {SWIW #4} 1	PORTAGE	-5233	-5404	-5531
34133244260000	LITSINGER 1	PORTAGE	-4822	-5002	-5127
34133244630000	KOSTENSKY 1	PORTAGE			0
34151258210000	CASTANEDA UNIT 1	STARK			0
34151258530000	HOSMER UNIT 1	STARK			0
34151258720000	RTB 1	STARK			0
34151244410000	HECK # 1	STARK			0
34151257680000	SOEHNLEN 2-9-9 8	STARK			0
34151249850000	HERSHBERGER D & A UNIT # 1	STARK			-4646
34151249700000	KIMMINS UNIT # 1	STARK		-4491	-4606
34151250600000	YODER UNIT # 1	STARK			-4615
34151249610000	RUEGG # 6	STARK			-4634
34151249710000	WHEELING & LAKE ERIE RR #1 # 8482-001	STARK	-4361	-4519	-4640
34151249380000	D. & M. HUFF #2 # 3836-001	STARK	-4365	-4524	-4639
34151243420000	S. & E. MILLER #1 # 2731-001	STARK			0
34151253710000	WEISGARBER 2-K	STARK	-4356	-4525	-4636
34151250580000	B ROTTMAN #2-K	STARK			0
34151250770000	WILSON-HERSHBERGER UNIT #4-K	STARK			-4673
34151250590000	ROTTMAN 1	STARK			-4649
34151250160000	VAUGHN UNIT #2-K	STARK	-4404	-4554	-4680
34151255460000	BREWSTER MOBILE HOMES 3	STARK	-4382	-4539	-4661
34151246010000	N. & W. RAILROAD #5 # 5	STARK	-4386	-4542	-4669
34151246370000	WOOD J ETAL COMM. 1 3318-001	STARK	-4506	-4670	-4781
34151251330000	DUTTON UNIT 1-32	STARK			-4754
34151250440000	WILSON-HERSHBERGER UNIT #3-K	STARK	-4398	-4561	-4682
34151246000000	N. & W. RAILROAD 6	STARK	-4373	-4562	-4683
34151252530000	N & W RAILROAD 7	STARK	-4370	-4530	-4645

34151248740000	G & L MARCHAND COMM 3-3492	STARK	-4443	-4593	-4718
34151250630000	WENTLING W & H COMM 2	STARK	-4459	-4611	-4717
34151250640000	STAHL V COMMUNITY #1	STARK	-4415	-4573	-4698
34151246660000	E. & M. HARROLD #2 # 3369-001	STARK	-4487	-4640	-4762
34151250130000	J. CLAY UNIT # 1	STARK		-4599	-4719
34151248200000	WEIRICH 1-3472	STARK	-4496	-4638	-4767
34151249140000	P. SOEHNLEN # 1-78	STARK	-4388	-4549	-4675
34151250980000	CLEANERS HANGER 2-A	STARK			-4796
34151246720000	WEISGARBER R & D Comm. 1	STARK			0
34151247350000	M. HARROLD COMM. #1A # 3408-001	STARK	-4512	-4681	-4804
34151250540000	DRAKE T 1	STARK			-4776
34151249620000	DIGLAW E 2 # 8160-001	STARK	-4338	-4494	-4611
34151246670000	RUSSELL BALTZLY #4 # 3370-001	STARK	-4548	-4706	-4836
34151249650000	MAUGER #2 8161-001-00	STARK	-4483	-4636	-4758
34151249990000	EBERHARDT O. COMM. 2-11916	STARK	-4464	-4621	-4742
34151250910000	HAWK E & N 3	STARK	-4345	-4503	-4626
34151257750000	MAJORS 1	STARK	-4407	-4564	-4690
34151249910000	INDORF D & M COMMUNITY # 3-11907	STARK	-4443	-4602	-4721
34151250120000	CHARTERS # 1-25	STARK			-4752
34151248140000	B & D LANDIS COMM 2	STARK	-4524	-4671	-4792
34151250150000	ZIMMER H & B 1	STARK	-4307	-4463	-4585
34151250500000	FAHRNI H & E COMMUNITY #1 # 12018-01	STARK			-4635
34151250780000	BRENNER UNIT #2	STARK			-4634
34151248100000	EBERLY UNIT # 1	STARK	-4542	-4684	-4821
34151246830000	J. WEBER # 2	STARK	-4528	-4704	-4808
34151250490000	SECRIST UNIT # 1	STARK			0
34151246980000	COURTNEY R & K COMM 1-3430	STARK			-4780
34151250110000	POLAND UNIT # 1-99	STARK			-4664
34151246970000	E. & M. HARROLD #3 # 3409-001	STARK	-4511	-4673	-4795
34151252680000	HENSEL UNIT 5-K	STARK			-4755
34151256800000	PSR 6	STARK			-4847
34151248320000	STARK WILDERNESS # 2	STARK	-4401	-4560	-4675
34151254750000	PSR 1	STARK			-4830
34151256810000	KEM 1	STARK			-4820
34151249160000	G & J GRABILL COMM #1 # 3800-001	STARK			-4703
34151251830000	DURISHIN UNIT 1-K	STARK	-4517	-4662	-4792
34151248190000	W & C BUCHER COMM. #3 # 3473-001	STARK	-4437	-4600	-4717
34151250070000	WALKER A # 3-8842	STARK	-4419	-4568	-4696
34151257550000	DC ROHR #1A A	STARK			-4714
34151243260000	R. G. EBERHARDT # 1-342704	STARK			-4735
34151251140000	FOSTER F COMM 2	STARK	-4530	-4701	-4804
34151251160000	P&V LAUTZENHEISER #U #2-K	STARK			-4772
34151250080000	FEICHTER M UNIT 1	STARK			-4697

34151250560000	ROHR E 2	STARK	-4456	-4616	-4738
34151250570000	ROHR 1	STARK	-4459	-4617	-4741
34151256110000	NFMWE 1	STARK			-4866
34151249920000	W & A SMITH #2-K	STARK	-4450	-4602	-4725
34151253840000	BRUGH UNIT 1-K	STARK	-4359	-4513	-4632
34151245270000	W & H KEGLEY COMMUNITY # 1-3223	STARK	-4500	-4670	-4766
34151250020000	WEFLER W # 8-11918	STARK	-4425	-4585	-4706
34151255470000	HENDRICKS UNIT 1-A	STARK			0
34151256600000	PSR 5	STARK	-4554	-4710	-4839
34151246300000	A. RUEGG ETAL #3 # 3306-001	STARK	-4554	-4725	-4851
34151250790000	BOWMAN D ET AL COMM 3	STARK	-4452	-4609	-4727
34151251510000	CARLONE UNIT 1	STARK	-4560	-4718	-4842
34151227760000	R & I HARTLINE COMM #1D # 804-001	STARK	-4576	-4728	-4851
34151251020000	BONANNO J COMMUNITY #1 12424-001-00	STARK	-4485	-4656	-4775
34151246310000	M. & L. KEIM ETAL #1 # 3308-001	STARK	-4490	-4649	-4777
34151245080000	G. ROHN # 1-A	STARK	-4530	-4702	-4814
34151252030000	NOFSINGER LOTTIE 2-K	STARK			-4840
34151245060000	INDORF D & M COMM. 2-3198-001	STARK	-4500	-4660	-4785
34151245190000	A. RUEGG # 2-3210	STARK	-4526	-4683	-4811
34151258140000	HAMMER 1-K	STARK	-4436	-4598	-4714
34151251480000	SCHALMO UNIT 1-K	STARK			-4919
34151249110000	G THOMAS UNIT #3-K-PLUG 5/98	STARK	-4572	-4714	-4845
34151249660000	GROVE # 1-K	STARK			-4767
34151246360000	D. FRITZ #1 # 3320-001	STARK			-4986
34151238300000	GONTER GEORGE & ELIZABETH 1-341311	STARK			0
34151257470000	DREVON 29-18-7 8	STARK	-5294	-5456	-5588
34151246330000	T. EDDY COMMUNITY #2 # 3316-001	STARK	-4596	-4757	-4884
34151254310000	DUERR R & E UNIT 2-K	STARK		-4963	-5093
34151258780000	JIM KLICK 2	STARK	-4685	-4847	-4969
34151253460000	PLOTT UNIT 2-K	STARK			0
34151257670000	PARADISE VALLEY FARMS 17-18-6 8	STARK	-5359	-5528	-5651
34151245370000	E. J. PLOTT & CO. INC. # 1-3224	STARK	-4756	-4909	-5038
34151251690000	MIHALIK T&S 1-12 539	STARK	-4741	-4910	-5027
34151245070000	JOHN'S SPORTING GOODS INC. # 1-3197	STARK	-4857	-5004	-5134
34151251070000	BINGHAM UNIT #2-K	STARK		-5237	-5368
34151251770000	A & C RAINIERI COMM 1	STARK	-4915	-5086	-5212
34151250890000	WOLF I COMMUNITY 2	STARK	-4950	-5116	-5241
34151250250000	VAUGHAN K & D COMMUNITY # 4-11980	STARK	-4915	-5077	-5200
34151257190000	R & E KRABILL UNIT 1-K	STARK	-4947	-5114	-5237
34151252280000	STROUBLE COMM A & L 5	STARK	-4955	-5123	-5252
34151258250000	MILLER W & M 4-K	STARK	-4924	-5082	-5211
34151257740000	SMITH RONALD 3-17-6 3	STARK	-5586	-5752	-5877

34151258400000	TESSMER H & M UNIT 1-K	STARK	-4952	-5116	-5237
34151258240000	MILLER O & K 2-K	STARK	-4950	-5119	-5244
34151258840000	KAKISH UNIT 1-K	STARK	-4931	-5094	-5219
34151258190000	KIKO 2-K	STARK	-4960	-5128	-5253
34151258830000	BURNS UNIT 1-K	STARK	-4932	-5101	-5229
34151258820000	RUFENERS CONGRESS LAKE UNIT 1-K	STARK	-4935	-5104	-5229
34151257990000	VAUGHAN UNIT 2-K	STARK	-4946	-5115	-5233
34151250260000	WOLF E & R COMMUNITY 1	STARK	-4959	-5121	-5247
34151255330000	VAUGHN UNIT ETAL 1A	STARK	-4939	-5108	-5231
34151258560000	H & H PROPERTIES 1-K	STARK	-4975	-5142	-5265
34151256300000	REEVES UNIT 3	STARK	-4966	-5134	-5258
34151258430000	MOORE H & L UNIT 1-K	STARK	-4983	-5148	-5276
34151251520000	BINGHAM 1	STARK			-5351
34151251280000	LINERODE 1-2941	STARK	-5086	-5253	-5375
34151250950000	MCCARTY G & B COMM #1 12290-001-00	STARK			-5306
34151251430000	KAPPER 3	STARK		-5255	-5384
34151251340000	KAPPER 1	STARK			-5366
34151251490000	FOX UNIT 2	STARK		-5238	-5365
34151251460000	WEISENT 33	STARK			-5366
34151251730000	KLODT UNIT 1-2982	STARK	-5107	-5279	-5403
34151252300000	PONTIUS UNIT 1-K	STARK			-5306
34151251270000	LINERODE 2-2942	STARK	-5131	-5301	-5423
34151251530000	KAPPER 2	STARK			0
34151257930000	ZUMKEHR 2-K	STARK	-5014	-5181	-5302
34151251310000	FOX 1-A	STARK		-5209	-5336
34151252430000	BINGHAM 3-K	STARK			-5309
34151250210000	S. SZEKELY COMM 2	STARK	-5069	-5250	-5365
34151249150000	JAMES MCCANN UNIT # 1	STARK			-5345
34151251500000	LINERODE 3-2943	STARK	-5099	-5266	-5403
34151250050000	WITTE UNIT #3-K	STARK	-5101	-5269	-5396
34151257620000	KIKO UNIT 1-K	STARK	-4952	-5124	-5248
34151250880000	DUFF J. COMM. #1 12240	STARK	-5047	-5211	-5336
34151228770000	REED 1	STARK			-5467
34151257000000	SCHNASE COMMUNITY 3	STARK	-5063	-5233	-5360
34151257890000	ROYER M & C 7-K	STARK	-5036	-5200	-5323
34151251880000	CITY OF ALLIANCE 2-2985	STARK	-5136	-5305	-5427
34151252290000	WITTE UNIT 4-K	STARK	-5070	-5235	-5359
34151248170000	P. MACARIE # 3	STARK			-5433
34151251870000	CITY OF ALLIANCE 3-2986	STARK	-5131	-5302	-5428
34151252340000	SLABACH UNIT 1-K	STARK			-5397
34151252210000	CLAPSADDLE UNIT 1-K	STARK	-5142	-5316	-5447
34151251890000	HAGAN UNIT 2-K	STARK			-5412

34151252750000	FRANK D & T 1-K	STARK	-5187	-5350	-5487
34151252380000	MILLER WILLIAM UNIT 1-K	STARK	-5145	-5313	-5443
34151252840000	THORNBERRY UNIT 1-K	STARK	-5145	-5315	-5446
34151252400000	MONTGOMERY UNIT 2-K	STARK		-5337	-5473
34151252350000	LINERODE TOM UNIT 1-K	STARK			0
34151253000000	ROBINSON G UNIT 1-K	STARK	-5186	-5352	-5488
34151252910000	HAZEN UNIT 1-K	STARK	-5226	-5395	-5529
34151249280000	MACARIE 4	STARK	-5142	-5307	-5438
34151253610000	WALKER JOHN UNIT 1-K	STARK	-5176	-5339	-5472
34151247510000	LOUISE BINGHAM & RALPH BINGHAM # 1	STARK			-5312
34151251010000	BINGHAM UNIT 1-K	STARK	-5066	-5233	-5356
34151248910000	WEISANT C & J COMM 2	STARK			-5264
34151250030000	SICKAFOOSE # 1-D	STARK			-5552
34151251550000	STONEHILL 4	STARK		-5658	-5791
34151250680000	YODER UNIT 2	STARK	-5462	-5622	-5752
34151250860000	BARLEY 1-2397	STARK	-5279	-5435	-5565
34151250850000	TANNER UNIT 1	STARK			-5739
34151235810000	STONEHILL 2	STARK	-5485	-5660	-5802
34151249780000	BELKNAP-SLAGEL UNIT # 1	STARK	-5638	-5808	-5949
34151250060000	BELKNAP # 2	STARK			-5850
34151250520000	HANNA UNIT # 1	STARK	-5673	-5838	-5969
34133244490000	KLINE POR	PORTAGE	-5071	-5247	-5374

Appendix 2 – Utica shale play wells used in the study. ISO values displayed are thickness of formation. API, Well Name, and thickness values in feet. PP=Point Pleasant; T/L=Trenton/Lexington.

UWI/API	WELLNAME	COUNTY	UTICA_ISO	PP_ISO	T/L ISO
34019221970000	BOWLING 23-16-6 10	CARROLL	153	133	0
34019226890000	PERRY UNIT 2S	CARROLL		0	0
34019220820000	WEST 4-15-5 3	CARROLL	161	137	64
34019221310000	OCEL 1S	CARROLL	170	139	0
34019219200000	HICKORY CLAY 12	CARROLL	163	125	74
34019221960000	KOVACH 3-15-6 1	CARROLL		0	0
34019220500000	ROBERTSON W & J UNIT 1	CARROLL	160	139	67
34019220810000	SHAW 20-14-5 5H	CARROLL	148	132	73
34019220840000	CONIGLIO 7-14-4 6	CARROLL		0	0
34019220890000	BAILEY 35-12-4 6	CARROLL	132	119	79
34019220680000	ROHR UNIT 1	CARROLL	166	126	74
34019222120000	KRUPRZAK 17-13-4 3	CARROLL	150	127	0
34019220900000	TANNER 24-12-4 10	CARROLL		0	0
34019221390000	P BROWN 9-13-5 1	CARROLL		0	0
34019221190000	SCOTT 24-12-5 3	CARROLL		0	0
34019221380000	TUCKOSH 35-11-4 1	CARROLL	126	124	78
34019220450000		CARROLL	162	129	71
34019220530000	MILLER 1	CARROLL	135	118	85
34019218770000	TOALSTON UNIT 1	CARROLL	162	125	78
34019218500000	BRYAN UNIT 1	CARROLL	146	128	73
34019220590000	WHITE 1	CARROLL	146	106	94
34029216940000	SANOR FARMS 23-17-5 3	COLUMBIANA	172	130	98
34029216970000	ARYVIEW ACRES 27-16-5 3	COLUMBIANA	161	131	78
34029218040000	ALTENHOF 10-15-4 3	COLUMBIANA		0	0
34029217190000	TREBILCOCK 25-15-4 1	COLUMBIANA		0	0
34029215930000	HEROLD 2-A	COLUMBIANA	167	136	69
34029215980000	SCHOENI NOB: GROSS2-A	COLUMBIANA		128	74
34029217050000	ALBANESO 24-14-4 8	COLUMBIANA		0	0
34029216020000	DENNY/STANLEY 1	COLUMBIANA	165	124	76
34029214750000	MULINIX ET AL # 1	COLUMBIANA		0	0
34029215210000	BLICKENSDERFER # 5	COLUMBIANA		125	74
34029215360000	WAFLER # 11	COLUMBIANA	168	139	65

34029215670000	DONALD L. DENNY # 2	COLUMBIANA	170	127	76
34029217060000	JANIE TRUST 5-12-3 1	COLUMBIANA	138	135	67
34029215910000	WOOLF W J WELL 3	COLUMBIANA	169	147	71
34029217240000	KERNICH 3-10-2 1	COLUMBIANA	160	137	0
34029216220000	ENTRIKIN UNIT 1	COLUMBIANA	171	130	54
34029215920000	CURFMAN 4	COLUMBIANA	160	131	71
34029216190000	F-P-S-M YOUNG 1	COLUMBIANA	170	135	70
34029217270000	CARNEY 17-7-1 3	COLUMBIANA	137	138	0
34029216040000	ALLIANCE/SEI UNIT 1	COLUMBIANA	178	126	75
34029216370000	SOWARDS UNIT 1-K	COLUMBIANA	167	131	69
34029214760000		COLUMBIANA	142	142	71
34067212350000	E CLARK SOUTH # 7	HARRISON		0	0
34067210650000	BOY SCOUT 1-33	HARRISON	125	121	61
34067210630000	STUART HENDERSON 11-12-6 3	HARRISON		0	0
34067210790000	GOTSHALL 14-12-5 3	HARRISON		0	0
34067209710000	PATTERSON ORVILLE 3	HARRISON	197	121	62
34067209430000	STEWART UNIT 5	HARRISON		0	0
34067210820000	CNXHAR10N5W 1P-23	HARRISON		0	0
34067207650000	G. BARRICKLOW # 1	HARRISON	178	126	60
34067209720000	PATTERSON ORVILLE 2	HARRISON	155	212	63
34067210620000	WAGNER 1	HARRISON	103	130	0
34067210570000	NORTH AMERICAN COAL ROYALTY CO BUELL	HARRISON	126	136	93
34067207640000	CLYDE VAN HORN # 1	HARRISON	131	97	68
34067205910000	B. BERRY # 1	HARRISON		0	0
34067208600000	PERKOWSKI-BOND # 2	HARRISON	119	139	0
34067207770000	D C JONES 7	HARRISON	142	143	77
34067211280000	CNXHAR 9N4W 1P-7A	HARRISON		0	0
34067207370000	ZECHMAN THOMAS # 1	HARRISON		0	0
34067210740000	CNXHAR9N5W 1P-24	HARRISON		0	0
34081205120000	VAHALIK 18-11-4 8	JEFFERSON		0	0
34081205070000	BROWN 36-11-3 10	JEFFERSON		0	0
34081205180000	DAILEY 28-10-3 3	JEFFERSON	142	126	90
34081205080000	ASUNCION WEST 15-11-3 3	JEFFERSON		0	0
34081205130000	DENOON 5-10-3 3	JEFFERSON		0	0
34081205010000	NORTH AMERICAN COAL 2-3	JEFFERSON	132	160	75
34081205280000	NAC 3P-20	JEFFERSON		0	0
34099228440000	BUCHS I & N 1-12 535	MAHONING	161	147	79
34099227640000	HAHLEN UNIT 3	MAHONING		0	0
34099202120000	BRENNER 1	MAHONING	173	136	74
34099227490000	COURTNEY UNIT # 5	MAHONING	159	118	72
34099231270000	NORTHSTAR (SWIW #10) 1	MAHONING	177	120	65
34099231570000	NORTHSTAR KHALIL (SWIW #11) 3	MAHONING	176	115	68
34099231710000	NORTHSTAR COLLINS (SWIW #13) 6	MAHONING	177	123	58

34099231580000	NORTHSTAR LUCKY (SWIW #12) 4	MAHONING	174	122	56
34133242600000	KOST 3-C	PORTAGE		0	0
34133244300000	ASHER PORT2AHSU	PORTAGE	161	126	72
34133244200000	HOSEY POR 6H-X	PORTAGE		0	0
34133244230000	MURVAY POR 8	PORTAGE		0	0
34133240460000	SIMON UNIT # 2	PORTAGE		0	83
34133238440000	WOODWARD # 1	PORTAGE		0	66
34133240400000	CAROLYN-KENT # 1	PORTAGE		0	84
34133236840000	CONLEY # 2	PORTAGE	198	93	89
34133240270000	WANTZ R UNIT # 1-2161	PORTAGE		76	64
34133240220000	KLEIN P & J COMM #1 # 8158-001	PORTAGE	165	125	69
34133238970000	BOYER # 1	PORTAGE		0	0
34133238100000	SCHAEFER # 1	PORTAGE		0	78
34133239620000	K & F VASHBINDER COMM. #1 # 3555-001	PORTAGE	166	120	77
34133244040000	M & L WOHLWEND 1-KA	PORTAGE	166	125	74
34133239270000	KISAMORE # 1	PORTAGE		0	71
34133244270000	EVANS W & C 2-K	PORTAGE	185	110	70
34133239280000	KISSEL # 2	PORTAGE		0	75
34133239710000	SCHAEFER # 2	PORTAGE		0	74
34133244130000	EVANS UNIT 1-K	PORTAGE		0	0
34133239630000	PETERSON # 1	PORTAGE	173	124	0
34133237140000	KINSEY UNIT # 1	PORTAGE	219	87	69
34133239150000	M & M STEFFEE COMM #1 # 3470-001	PORTAGE	166	120	74
34133240000000	PERO # 1	PORTAGE		0	78
34133244670000	K & W EVANS 4-K	PORTAGE		0	74
34133244080000	MAY 1-K	PORTAGE		0	0
34133239650000	HUDACSEK # 1	PORTAGE	162	129	76
34133239940000	LINDEMAN # 1	PORTAGE		0	82
34133239380000	C & R STEPHENS COMM 1-3483	PORTAGE	173	118	79
34133237780000	CONNOR C COMM 1	PORTAGE	170	127	69
34133239520000	R & C LOREE COMM 3491-001	PORTAGE	165	122	82
34133238400000	D. & F. CUNNINGHAM COMM. #1 # 3437-001	PORTAGE	160	133	77
34133239730000	LAUBURT # 1	PORTAGE		0	82
34133240280000	HYDE P P COMM 1 # 8473-001	PORTAGE	166	123	76
34133239530000	WISE D & L COMM 3496-01	PORTAGE	166	121	79
34133239450000	BOOHER # 1	PORTAGE		0	86
34133239460000	W. HANKEY ETAL COMM. #2 # 4384-001	PORTAGE	170	119	76
34133203360000	ALVIN ROTHERMEL COMM #1D # 388-001	PORTAGE	163	128	76
34133239220000	J. HOUCK COMM.#1 # 3471-001	PORTAGE	171	122	82
34133238750000	OLIVER # 1	PORTAGE		0	76
34133238880000	W.R. TRUOG # 2-1564	PORTAGE	217	88	97
34133239420000	BAILEY # 1	PORTAGE		0	76
34133239370000	WISE # 1	PORTAGE	159	132	74
34133238610000	V PLOSKUNAK COMM 1	PORTAGE	166	123	98

34133239470000	WISE UNIT 2	PORTAGE		0	79
34133238090000	KLINE # 1	PORTAGE		0	74
34133239670000	CLINTON PETROLEUM COMM #2 # 3557-001	PORTAGE	184	116	74
34133239860000	BORDENKIRCHER # 1	PORTAGE		0	76
34133239760000	KIDIKAS # 1	PORTAGE		0	76
34133239680000	W. WISE # 1	PORTAGE	169	120	76
34133239430000	ST JOSEPH 1	PORTAGE	163	128	76
34133239750000	CLIFFORD UNIT # 3-1851	PORTAGE	169	118	80
34133239510000	JAMES & SHIRLEY HOUSE 3	PORTAGE	169	122	76
34133238260000	OFM CO COMM 1	PORTAGE	158	129	78
34133239080000	W. MCGRATH ETAL COMM.#1 # 3469-001	PORTAGE	166	123	71
34133240660000	WINNEFELD # 1-2253	PORTAGE	171	126	73
34133239490000	R WARD COMM #1 # 3485-001	PORTAGE	168	125	69
34133237940000	R &E ARTIM COMM 1	PORTAGE	172	130	70
34133240320000	SIEGFERTH J & E COMM #1 # 8488-001	PORTAGE	168	119	79
34133237770000	BOOHER # 2A	PORTAGE	167	128	74
34133241250000	RICE RR1	PORTAGE		0	0
34133241760000	KERR 1	PORTAGE		0	75
34133241650000	BLACKMAN 1	PORTAGE	165	122	66
34133238910000	A. KNECHT ETAL COMM. #2 # 3448-001	PORTAGE	167	133	69
34133241630000	BOOHER 1	PORTAGE	167	122	80
34133241790000	METZNER 4	PORTAGE		0	72
34133240240000	BROCKETT # 5	PORTAGE		0	76
34133241480000	TYMCIO 1	PORTAGE		0	78
34133241670000	RICE 3	PORTAGE		0	69
34133241770000	FLOWERS 1	PORTAGE	169	125	73
34133239180000	RUDD # 1	PORTAGE		0	75
34133241490000	METZNER 1	PORTAGE	170	141	60
34133240190000	F. & G. RODENBUCHER COMM. #1 # 3835-001	PORTAGE	168	120	81
34133241500000	METZNER 2	PORTAGE		0	74
34133241300000	DARRAH 2	PORTAGE		0	0
34133241820000	BRADLEY 3	PORTAGE		0	64
34133241660000	RICE 2	PORTAGE		0	0
34133241840000	RIPLEY UNIT 1	PORTAGE	173	126	69
34133241610000	NEWHART-MILLER UNIT 4	PORTAGE		0	85
34133241620000	NEWHART-MILLER UNIT 6	PORTAGE	168	126	81
34133241560000	WOLFF B UNIT 1-2383	PORTAGE	173	117	79
34133241550000	KENNEDY 2-2368	PORTAGE	167	121	76
34133241830000	FLOWERS 2	PORTAGE	171	129	71
34133242120000	TIMMS 1	PORTAGE		0	79
34133239810000	HORNING # 1	PORTAGE		0	72
34133239820000	C & P WISE COMM 1	PORTAGE		0	0
34133240130000	DUNKLE # 1	PORTAGE		0	76
34133241870000	SNYDER S COMM 1	PORTAGE	159	131	80

34133240650000	HILL W & A ETAL COMMUNITY # 1-8838	PORTAGE	174	123	78
34133241070000	BRANNON D W 1	PORTAGE		0	76
34133238790000	R. & K. HILGERT #1 # 3447-001	PORTAGE	171	120	76
34133240090000	J. E. & S. M. DAVIS COMM. #1 # 3690-001	PORTAGE	166	127	71
34133240120000	TIRE TREAD DEVELOPMENT COMM. #1 # 3691-0	PORTAGE	170	123	73
34133240330000	FOX W COMM #2 # 8489-001	PORTAGE	171	122	84
34133240390000	RICHARDS # 2	PORTAGE		0	0
34133241690000	SMITH D 6	PORTAGE		0	74
34133240230000	BROCKETT # 4	PORTAGE		0	74
34133239850000	HALL # 1	PORTAGE		0	83
34133239830000	D & R D'AGOSTINE COMM #1 # 3562-001	PORTAGE	168	122	75
34133240180000	MILLER # 1	PORTAGE		0	78
34133241430000	HERBRUCK #2-K	PORTAGE		0	76
34133240160000	MANHOLT UNIT 3	PORTAGE		0	75
34133242490000	PUGH 3	PORTAGE		0	80
34133240370000	CAHILL # 1	PORTAGE		0	84
34133241850000	SNYDER S COMM #2 12231-001-00	PORTAGE	163	137	67
34133239720000	FRITZ # 1-A	PORTAGE	175	130	69
34133240790000	WISE # 2-RR	PORTAGE		0	77
34133241340000	MINEAR UNIT 2	PORTAGE	170	123	76
34133240170000	STOTLER 1	PORTAGE		0	76
34133240580000	BOWMAN 2	PORTAGE		0	84
34133240740000	PAMER UNIT 3	PORTAGE		0	80
34133240430000	RICHARDS UNIT 2	PORTAGE		0	80
34133241570000	KIRKLAND M & A COMM 1	PORTAGE	166	122	75
34133241450000	FREEMAN UNIT #2-K	PORTAGE		0	78
34133240410000	PAMER # 2	PORTAGE		0	77
34133241590000	KOST T & M 1-RR	PORTAGE		0	0
34133241090000	M. SMITH #1 12119-01	PORTAGE	164	118	81
34133239870000	T & M MCGUIRE COMM. #1 # 3563-001	PORTAGE	168	126	72
34133240250000	MEREDITH # 3	PORTAGE		0	76
34133241130000	MCKNIGHT # 2-RR	PORTAGE		0	71
34133239950000	R & L SLAUGHTER COMM. #1 # 3687-001	PORTAGE	165	124	80
34133240480000	CORL UNIT # 1-2227	PORTAGE		0	71
34133240550000	MCGUIRE T & M # 2-11845	PORTAGE	169	124	73
34133240890000	CRAMNER # 4-2304	PORTAGE	169	127	76
34133240140000	ACORD UNIT # 1	PORTAGE		0	80
34133240150000	WALLBROWN # 2	PORTAGE		0	74
34133242410000	PUGH 2	PORTAGE		0	71
34133240560000	COGAN S COMMUNITY # 11846-1	PORTAGE	171	120	79
34133242450000	GODFREY UNIT 1-RR	PORTAGE		0	85
34133240990000	GROSSENBACHER UNIT 1	PORTAGE		0	74
34133240980000	ZAVARA-KIBLER UNIT 2	PORTAGE		0	75

34133241780000	METZNER 3	PORTAGE		0	81
34133240600000	EBIE # 4	PORTAGE		0	71
34133241080000	DUMONT P & R COMMUNITY #1 12114-001-	PORTAGE	166	116	79
34133242430000	JONES 1	PORTAGE		106	70
34133241240000	REED # RR1	PORTAGE		0	0
34133240040000	WALLBROWN 4	PORTAGE		0	72
34133243870000	LOCKHART UNIT 1	PORTAGE	171	127	72
34133238410000	A. & S. SCRUGGS COMM. #1 # 3438-001	PORTAGE	166	124	74
34133241520000	PUGH UNIT 1	PORTAGE		0	74
34133242660000	KILGORE 1	PORTAGE		0	0
34133241800000	JACKSON 1	PORTAGE	181	120	76
34133242310000	DEERFIELD FARMS 5	PORTAGE		0	77
34133236120000	MEREDITH UNIT # 1	PORTAGE		0	72
34133240340000	PLYMALE UNIT 1	PORTAGE		0	77
34133241350000	SMITH D 5	PORTAGE		119	81
34133242210000	BAUMAN P 15	PORTAGE	180	123	89
34133241860000	SNYDER W & S 1	PORTAGE	160	131	72
34133240500000	SPELLMAN JAMES A & ALICE M # 11844	PORTAGE	165	128	74
34133240640000	EBIE # 5	PORTAGE		0	76
34133240670000	WISE UNIT # 2-A	PORTAGE		0	80
34133240610000	WISE UNIT # 1	PORTAGE		0	0
34133241120000	MOLEDOR-RAFFERTY 2	PORTAGE		132	72
34133241040000	LEIENDECKER R & J 1	PORTAGE	179	116	81
34133241600000	NEWHART-MILLER UNIT 5	PORTAGE	171	127	93
34133242520000	ABBE 4	PORTAGE		0	71
34133241740000	GEIB G & D COMMUNITY 1	PORTAGE	163	122	74
34133242810000	FINNEGAN 4	PORTAGE		122	79
34133240590000	WALKER UNIT # 2	PORTAGE		0	75
34133242250000	ANDERSON 1	PORTAGE		0	85
34133239910000	KOLASKY # 1	PORTAGE		0	79
34133240730000	GAY # 2	PORTAGE		0	73
34133240490000	BARNETT # 2 K-W	PORTAGE		0	74
34133239580000	DANKO # 1	PORTAGE		0	0
34133241200000	KOST T ETAL # 2	PORTAGE		0	75
34133244640000	SMITH W & N 4-K	PORTAGE	176	125	88
34133240900000	CRAMNER # 3-2303	PORTAGE	173	126	74
34133239800000	MCKAY # 1	PORTAGE		0	71
34133240210000	STRADER J & S COMM #1 # 7770-001	PORTAGE	168	120	74
34133242330000	WISE H & O 3	PORTAGE		0	73
34133239030000	C. & M. BINGHAM COMM. #1 # 3459-001	PORTAGE	165	123	62
34133239780000	BAILEY-DAVIS # 2-1565	PORTAGE		0	74
34133241810000	WASS P-7	PORTAGE	188	134	59
34133242350000	DEMYAN 2	PORTAGE		0	71

34133242020000	WILKERSON 1	PORTAGE		0	0
34133240720000	EBIE 6	PORTAGE		0	74
34133240030000	WALLBROWN # 3	PORTAGE		0	74
34133241140000	MASSA F & C 1	PORTAGE		0	75
34133242750000	ENGLEHART 2	PORTAGE		0	69
34133240940000	AMLIN UNIT 1	PORTAGE		0	0
34133242500000	SCHULTZ LAKE UNIT 1	PORTAGE		0	71
34133242510000	FINEGAN UNIT 2	PORTAGE		0	79
34133239790000	DANKO # 2	PORTAGE		0	69
34133241150000	REESE UNIT # 1	PORTAGE		0	80
34133240920000	DORNAN 2	PORTAGE		0	79
34133241110000	DEERFIELD LANDS 1-2342	PORTAGE		0	76
34133241160000	DORNAN # 1	PORTAGE		0	69
34133241290000	H & O WISE #2	PORTAGE		0	80
34133239840000	DANKO # 3	PORTAGE		0	73
34133239920000	HOLLENDONNER 1	PORTAGE		0	75
34133240800000	WISE UNIT # 3	PORTAGE		0	77
34133241710000	SANDERS UNIT 2-K	PORTAGE		0	83
34133241970000	DEMYAN 1	PORTAGE		0	76
34133242300000	KOST 2	PORTAGE		0	0
34133242400000	ABBE UNIT 2	PORTAGE		0	80
34133242440000	MOFF UNIT 2-K	PORTAGE		0	0
34133239590000	KEMPH # 2	PORTAGE		0	0
34133238730000	GEIGER # 1	PORTAGE		0	74
34133240860000	GAY # 3	PORTAGE		0	0
34133241020000	RICHARDS W ET AL COMM #1 12086-001-	PORTAGE	176	116	73
34133242000000	DEERFIELD FARMS RR 1-A	PORTAGE		0	85
34133240700000	MCBROOM UNIT 1	PORTAGE		0	73
34133241310000	RYAN UNIT 1	PORTAGE		0	80
34133242090000	SHEWELL UNIT P-11	PORTAGE	171	122	94
34133242140000	DEERFIELD FARMS R.R. 3	PORTAGE		0	73
34133240100000	KINSEY 1	PORTAGE		0	75
34133242390000	EDWARDS 1	PORTAGE		0	77
34133240850000	WISE # 1	PORTAGE		0	80
34133242070000	PITTMAN 2	PORTAGE		0	76
34133242150000	DEERFIELD FARMS RR 4	PORTAGE		0	75
34133242320000	GRAHAM 1 RR	PORTAGE		0	0
34133240810000	CRAIN UNIT # 2K-W	PORTAGE		0	75
34133241720000	PORTAGE-BURKEY UNIT #2-K	PORTAGE		0	73
34133242220000	DEERFIELD FARMS R.R. 2	PORTAGE		0	0
34133242280000	HORN 1	PORTAGE		0	76
34133240200000	JENKINS # 1	PORTAGE		0	75
34133243040000	ABBE 5	PORTAGE		0	75

34133239960000	BURKHEAD # 1	PORTAGE		0	75
34133241940000	LANTZ 2-K	PORTAGE		0	72
34133242200000	EHASZ P14	PORTAGE	173	122	81
34133244510000	RUGGLES 3-K	PORTAGE	174	134	57
34133240840000	WOODS UNIT # 2	PORTAGE	171	123	85
34133241930000	KAINRAD P-8	PORTAGE	173	130	86
34133242760000	MYERS G & L UNIT 1-RR	PORTAGE		0	79
34133240420000	SCOTT HEIRS UNIT #2	PORTAGE	170	143	88
34133244070000	PANDER UNIT 1	PORTAGE	172	127	65
34133242680000	SCOTT HEIRS 3	PORTAGE	182	128	91
34133239890000	DITTMER # 2	PORTAGE		0	70
34133240870000	KARAS # 16	PORTAGE		0	75
34133240820000	VENCE-HAISS UNIT # 2	PORTAGE		0	84
34133228600000	VIKING RESOURCES CORP. {SWIW #4} 1	PORTAGE	170	127	90
34133244260000	LITSINGER 1	PORTAGE	180	125	69
34133244630000	KOSTENSKY 1	PORTAGE		0	0
34151258210000	CASTANEDA UNIT 1	STARK		0	0
34151258530000	HOSMER UNIT 1	STARK		0	0
34151258720000	RTB 1	STARK		0	0
34151244410000	HECK # 1	STARK		0	0
34151257680000	SOEHNLEN 2-9-9 8	STARK		0	0
34151249850000	HERSHBERGER D & A UNIT # 1	STARK		0	54
34151249700000	KIMMINS UNIT # 1	STARK		115	55
34151250600000	YODER UNIT # 1	STARK		0	55
34151249610000	RUEGG # 6	STARK		0	70
34151249710000	WHEELING & LAKE ERIE RR #1 # 8482-001	STARK	159	121	71
34151249380000	D. & M. HUFF #2 # 3836-001	STARK	160	114	75
34151243420000	S. & E. MILLER #1 # 2731-001	STARK		0	0
34151253710000	WEISGARBER 2-K	STARK	169	111	66
34151250580000	B ROTTMAN #2-K	STARK		0	0
34151250770000	WILSON-HERSHBERGER UNIT #4-K	STARK		0	75
34151250590000	ROTTMAN 1	STARK		0	56
34151250160000	VAUGHN UNIT #2-K	STARK	150	126	66
34151255460000	BREWSTER MOBILE HOMES 3	STARK	157	123	55
34151246010000	N. & W. RAILROAD #5 # 5	STARK	157	127	66
34151246370000	WOOD J ETAL COMM. 1 3318-001	STARK	164	111	73
34151251330000	DUTTON UNIT 1-32	STARK		0	70
34151250440000	WILSON-HERSHBERGER UNIT #3-K	STARK	162	121	69
34151246000000	N. & W. RAILROAD 6	STARK	189	122	68
34151252530000	N & W RAILROAD 7	STARK	160	115	78
34151248740000	G & L MARCHAND COMM 3-3492	STARK	150	125	62
34151250630000	WENTLING W & H COMM 2	STARK	151	107	68
34151250640000	STAHL V COMMUNITY #1	STARK	159	125	68

34151246660000	E. & M. HARROLD #2 # 3369-001	STARK	153	122	66
34151250130000	J. CLAY UNIT # 1	STARK		119	59
34151248200000	WEIRICH 1-3472	STARK	142	129	68
34151249140000	P. SOEHNLEN # 1-78	STARK	161	127	50
34151250980000	CLEANERS HANGER 2-A	STARK		0	58
34151246720000	WEISGARBER R & D Comm. 1	STARK	151	130	68
34151247350000	M. HARROLD COMM. #1A # 3408-001	STARK	169	123	69
34151250540000	DRAKE T 1	STARK		0	70
34151249620000	DIGLAW E 2 # 8160-001	STARK	156	117	72
34151246670000	RUSSELL BALTZLY #4 # 3370-001	STARK	158	130	72
34151249650000	MAUGER #2 8161-001-00	STARK	153	123	71
34151249990000	EBERHARDT O. COMM. 2-11916	STARK	157	121	68
34151250910000	HAWK E & N 3	STARK	158	123	56
34151257750000	MAJORS 1	STARK	157	126	65
34151249910000	INDORF D & M COMMUNITY # 3-11907	STARK	159	119	72
34151250120000	CHARTERS # 1-25	STARK		0	75
34151248140000	B & D LANDIS COMM 2	STARK	147	121	73
34151250150000	ZIMMER H & B 1	STARK	155	122	73
34151250500000	FAHRNI H & E COMMUNITY #1 # 12018-01	STARK		0	72
34151250780000	BRENNER UNIT #2	STARK		0	68
34151248100000	EBERLY UNIT # 1	STARK	142	137	64
34151246830000	J. WEBER # 2	STARK	176	103	68
34151250490000	SECRIST UNIT # 1	STARK		0	0
34151246980000	COURTNEY R & K COMM 1-3430	STARK		0	70
34151250110000	POLAND UNIT # 1-99	STARK		0	70
34151246970000	E. & M. HARROLD #3 # 3409-001	STARK	162	122	68
34151252680000	HENSEL UNIT 5-K	STARK		0	65
34151256800000	PSR 6	STARK		0	95
34151248320000	STARK WILDERNESS # 2	STARK	160	114	62
34151254750000	PSR 1	STARK		0	72
34151256810000	KEM 1	STARK		0	84
34151249160000	G & J GRABILL COMM #1 # 3800-001	STARK		0	69
34151251830000	DURISHIN UNIT 1-K	STARK	146	130	64
34151248190000	W & C BUCHER COMM. #3 # 3473-001	STARK	163	116	66
34151250070000	WALKER A # 3-8842	STARK	150	128	74
34151257550000	DC ROHR #1A A	STARK		0	65
34151243260000	R. G. EBERHARDT # 1-342704	STARK		0	72
34151251140000	FOSTER F COMM 2	STARK	171	102	71
34151251160000	P&V LAUTZENHEISER #U #2-K	STARK		0	66
34151250080000	FEICHTER M UNIT 1	STARK		0	71
34151250560000	ROHR E 2	STARK	160	122	82
34151250570000	ROHR 1	STARK	157	124	80
34151256110000	NFMWE 1	STARK		0	64

34151249920000	W & A SMITH #2-K	STARK	152	124	66
34151253840000	BRUGH UNIT 1-K	STARK	154	119	70
34151245270000	W & H KEGLEY COMMUNITY # 1-3223	STARK	171	96	73
34151250020000	WEFLER W # 8-11918	STARK	160	120	79
34151255470000	HENDRICKS UNIT 1-A	STARK		0	0
34151256600000	PSR 5	STARK	157	128	78
34151246300000	A. RUEGG ETAL #3 # 3306-001	STARK	171	126	63
34151250790000	BOWMAN D ET AL COMM 3	STARK	157	118	63
34151251510000	CARLONE UNIT 1	STARK	158	124	68
34151227760000	R & I HARTLINE COMM #1D # 804-001	STARK	152	123	66
34151251020000	BONANNO J COMMUNITY #1 12424-001-00	STARK	171	119	64
34151246310000	M. & L. KEIM ETAL #1 # 3308-001	STARK	159	128	68
34151245080000	G. ROHN # 1-A	STARK	172	113	70
34151252030000	NOFSINGER LOTTIE 2-K	STARK		0	62
34151245060000	INDORF D & M COMM. 2-3198-001	STARK	160	125	84
34151245190000	A. RUEGG # 2-3210	STARK	157	128	68
34151258140000	HAMMER 1-K	STARK	163	116	70
34151251480000	SCHALMO UNIT 1-K	STARK		0	55
34151249110000	G THOMAS UNIT #3-K-PLUG 5/98	STARK	142	131	68
34151249660000	GROVE # 1-K	STARK		0	64
34151246360000	D. FRITZ #1 # 3320-001	STARK		0	67
34151238300000	GONTER GEORGE & ELIZABETH 1-341311	STARK		0	0
34151257470000	DREVON 29-18-7 8	STARK	162	132	61
34151246330000	T. EDDY COMMUNITY #2 # 3316-001	STARK	162	127	60
34151254310000	DUERR R & E UNIT 2-K	STARK		131	58
34151258780000	JIM KLICK 2	STARK	162	122	69
34151253460000	PLOTT UNIT 2-K	STARK	157	122	75
34151257670000	PARADISE VALLEY FARMS 17-18-6 8	STARK	169	122	80
34151245370000	E. J. PLOTT & CO. INC. # 1-3224	STARK	153	130	64
34151251690000	MIHALIK T&S 1-12 539	STARK	169	118	79
34151245070000	JOHN'S SPORTING GOODS INC. # 1-3197	STARK	147	131	63
34151251070000	BINGHAM UNIT #2-K	STARK		132	72
34151251770000	A & C RAINIERI COMM 1	STARK	171	125	73
34151250890000	WOLF I COMMUNITY 2	STARK	166	125	76
34151250250000	VAUGHAN K & D COMMUNITY # 4-11980	STARK	163	123	87
34151257190000	R & E KRABILL UNIT 1-K	STARK	167	123	78
34151252280000	STROUBLE COMM A & L 5	STARK	168	129	72
34151258250000	MILLER W & M 4-K	STARK	159	129	73
34151257740000	SMITH RONALD 3-17-6 3	STARK	165	125	81
34151258400000	TESSMER H & M UNIT 1-K	STARK	164	121	80
34151258240000	MILLER O & K 2-K	STARK	169	125	75
34151258840000	KAKISH UNIT 1-K	STARK	163	125	78

34151258190000	KIKO 2-K	STARK	168	125	75
34151258830000	BURNS UNIT 1-K	STARK	169	128	70
34151258820000	RUFENERS CONGRESS LAKE UNIT 1-K	STARK	169	125	76
34151257990000	VAUGHAN UNIT 2-K	STARK	169	118	83
34151250260000	WOLF E & R COMMUNITY 1	STARK	161	126	81
34151255330000	VAUGHN UNIT ETAL 1A	STARK	169	123	78
34151258560000	H & H PROPERTIES 1-K	STARK	168	122	73
34151256300000	REEVES UNIT 3	STARK	168	124	81
34151258430000	MOORE H & L UNIT 1-K	STARK	165	128	75
34151251520000	BINGHAM 1	STARK		0	90
34151251280000	LINERODE 1-2941	STARK	167	122	82
34151250950000	MCCARTY G & B COMM #1 12290-001-00	STARK		0	80
34151251430000	KAPPER 3	STARK		129	72
34151251340000	KAPPER 1	STARK		0	84
34151251490000	FOX UNIT 2	STARK		127	78
34151251460000	WEISENT 33	STARK		0	82
34151251730000	KLODT UNIT 1-2982	STARK	172	124	78
34151252300000	PONTIUS UNIT 1-K	STARK		0	73
34151251270000	LINERODE 2-2942	STARK	170	123	84
34151251530000	KAPPER 2	STARK		0	0
34151257930000	ZUMKEHR 2-K	STARK	166	121	84
34151251310000	FOX 1-A	STARK		127	76
34151252430000	BINGHAM 3-K	STARK		0	69
34151250210000	S. SZEKELY COMM 2	STARK	180	116	74
34151249150000	JAMES MCCANN UNIT # 1	STARK		0	78
34151251500000	LINERODE 3-2943	STARK	166	137	72
34151250050000	WITTE UNIT #3-K	STARK	167	127	80
34151257620000	KIKO UNIT 1-K	STARK	171	124	75
34151250880000	DUFF J. COMM. #1 12240	STARK	164	125	81
34151228770000	REED 1	STARK		0	68
34151257000000	SCHNASE COMMUNITY 3	STARK	170	127	74
34151257890000	ROYER M & C 7-K	STARK	164	122	81
34151251880000	CITY OF ALLIANCE 2-2985	STARK	168	122	86
34151252290000	WITTE UNIT 4-K	STARK	165	124	82
34151248170000	P. MACARIE # 3	STARK		0	81
34151251870000	CITY OF ALLIANCE 3-2986	STARK	170	126	82
34151252340000	SLABACH UNIT 1-K	STARK		0	76
34151252210000	CLAPSADDLE UNIT 1-K	STARK	174	131	89
34151251890000	HAGAN UNIT 2-K	STARK		0	80
34151252750000	FRANK D & T 1-K	STARK	163	137	76
34151252380000	MILLER WILLIAM UNIT 1-K	STARK	168	130	76
34151252840000	THORNBERRY UNIT 1-K	STARK	170	130	76
34151252400000	MONTGOMERY UNIT 2-K	STARK		136	76
34151252350000	LINERODE TOM UNIT 1-K	STARK		0	0
34151253000000	ROBINSON G UNIT 1-K	STARK	166	136	71

34151252910000	HAZEN UNIT 1-K	STARK	168	135	76
34151249280000	MACARIE 4	STARK	165	131	74
34151253610000	WALKER JOHN UNIT 1-K	STARK	163	132	78
34151247510000	LOUISE BINGHAM & RALPH BINGHAM # 1	STARK		0	72
34151251010000	BINGHAM UNIT 1-K	STARK	167	123	78
34151248910000	WEISANT C & J COMM 2	STARK		0	81
34151250030000	SICKAFOOSE # 1-D	STARK		0	67
34151251550000	STONEHILL 4	STARK		132	76
34151250680000	YODER UNIT 2	STARK	160	130	79
34151250860000	BARLEY 1-2397	STARK	156	130	78
34151250850000	TANNER UNIT 1	STARK		0	76
34151235810000	STONEHILL 2	STARK	175	142	81
34151249780000	BELKNAP-SLAGEL UNIT # 1	STARK	170	141	81
34151250060000	BELKNAP # 2	STARK		0	83
34151250520000	HANNA UNIT # 1	STARK	164	131	79
34133244490000	KLINE POR	PORTAGE	176	127	0

Appendix 3 – API, Well Name, and Formation Boundary value in feet below sea level for the Black River Limestone.

UWI/API	WELLNAME	COUNTY	BLACK_RIVER
34019219200000	HICKORY CLAY 12	CARROLL	-5747
34019220450000		CARROLL	-5826
34019220500000	ROBERTSON W & J UNIT 1	CARROLL	-5921
34019220680000	ROHR UNIT 1	CARROLL	-6102
34019220820000	WEST 4-15-5 3	CARROLL	-6417
34019220530000	MILLER 1	CARROLL	-6528
34019220810000	SHAW 20-14-5 5H	CARROLL	-6652
34019218770000	TOALSTON UNIT 1	CARROLL	-6703
34019218500000	BRYAN UNIT 1	CARROLL	-6762
34019220590000	WHITE 1	CARROLL	-6806
34019220890000	BAILEY 35-12-4 6	CARROLL	-6998
34019221380000	TUCKOSH 35-11-4 1	CARROLL	-7211
34029215210000	BLICKENSDERFER # 5	COLUMBIANA	-6068
34029216020000	DENNY/STANLEY 1	COLUMBIANA	-6110
34029215980000	SCHOENI NOB: GROSS2-A	COLUMBIANA	-6121
34029214750000	MULINIX ET AL # 1	COLUMBIANA	-6134
34029215670000	DONALD L. DENNY # 2	COLUMBIANA	-6136
34029215930000	HEROLD 2-A	COLUMBIANA	-6137
34029215360000	WAFLER # 11	COLUMBIANA	-6179
34029216940000	SANOR FARMS 23-17-5 3	COLUMBIANA	-6199
34029215910000	WOOLF W J WELL 3	COLUMBIANA	-6252
34029215920000	CURFMAN 4	COLUMBIANA	-6334
34029216970000	ARYVIEW ACRES 27-16-5 3	COLUMBIANA	-6389
34029216040000	ALLIANCE/SEI UNIT 1	COLUMBIANA	-6666
34029216220000	ENTRIKIN UNIT 1	COLUMBIANA	-6678
34029216190000	F-P-S-M YOUNG 1	COLUMBIANA	-6707
34029216370000	SOWARDS UNIT 1-K	COLUMBIANA	-7147
34029214760000		COLUMBIANA	-7175
34029217060000	JANIE TRUST 5-12-3 1	COLUMBIANA	-7327
34067207650000	G. BARRICKLOW # 1	HARRISON	-6293
34067209710000	PATTERSON ORVILLE 3	HARRISON	-6334
34067209720000	PATTERSON ORVILLE 2	HARRISON	-6407

34067207640000	CLYDE VAN HORN # 1	HARRISON	-6586
34067210650000	BOY SCOUT 1-33	HARRISON	-6773
34067207770000	D C JONES 7	HARRISON	-6963
34067210570000	NORTH AMERICAN COAL ROYALTY CO BUELL	HARRISON	-7266
34081205180000	DAILEY 28-10-3 3	JEFFERSON	-7563
34099228440000	BUCHS I & N 1-12 535	MAHONING	-5747
34099202120000	BRENNER 1	MAHONING	-5784
34099227490000	COURTNEY UNIT # 5	MAHONING	-5982
34099231270000	NORTHSTAR (SWIW #10) 1	MAHONING	-6297
34099231570000	NORTHSTAR KHALIL (SWIW #11) 3	MAHONING	-6362
34099231710000	NORTHSTAR COLLINS (SWIW #13) 6	MAHONING	-6494
34099231580000	NORTHSTAR LUCKY (SWIW #12) 4	MAHONING	-6629
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34133240460000	SIMON UNIT # 2	PORTAGE	-4871
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34133238090000	KLINE # 1	PORTAGE	-4980
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34133239620000	K & F VASHBINDER COMM. #1 # 3555-001	PORTAGE	-5035
34133239270000	KISAMORE # 1	PORTAGE	-5037
34133240660000	WINNEFELD # 1-2253	PORTAGE	-5037
34133244040000	M & L WOHLWEND 1-KA	PORTAGE	-5040
34133244670000	K & W EVANS 4-K	PORTAGE	-5046
34133244300000	ASHER PORT2AHSU	PORTAGE	-5050
34133239750000	CLIFFORD UNIT # 3-1851	PORTAGE	-5080
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34133239710000	SCHAEFER # 2	PORTAGE	-5098
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34133239470000	WISE UNIT 2	PORTAGE	-5107
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34133239420000	BAILEY # 1	PORTAGE	-5134
34133237770000	BOOHER # 2A	PORTAGE	-5134
34133239030000	C. & M. BINGHAM COMM. #1 # 3459-001	PORTAGE	-5134
34133239680000	W. WISE # 1	PORTAGE	-5135
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34133239860000	BORDENKIRCHER # 1	PORTAGE	-5136
34133239370000	WISE # 1	PORTAGE	-5140
34133238730000	GEIGER # 1	PORTAGE	-5141
34133240280000	HYDE P P COMM 1 # 8473-001	PORTAGE	-5145
34133238880000	W.R. TRUOG # 2-1564	PORTAGE	-5145
34133239450000	BOOHER # 1	PORTAGE	-5153
34133239220000	J. HOUCK COMM.#1 # 3471-001	PORTAGE	-5163
34133241630000	BOOHER 1	PORTAGE	-5168
34133239670000	CLINTON PETROLEUM COMM #2 # 3557-001	PORTAGE	-5171
34133239460000	W. HANKEY ETAL COMM. #2 # 4384-001	PORTAGE	-5175
34133239730000	LAUBURT # 1	PORTAGE	-5176
34133239080000	W. MCGRATH ETAL COMM.#1 # 3469-001	PORTAGE	-5176
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34133239940000	LINDEMAN # 1	PORTAGE	-5183
34133237780000	CONNOR C COMM 1	PORTAGE	-5184
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34133238610000	V PLOSKUNAK COMM 1	PORTAGE	-5188
34133238260000	OFM CO COMM 1	PORTAGE	-5195
34133244260000	LITSINGER 1	PORTAGE	-5196
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34133241770000	FLOWERS 1	PORTAGE	-5223
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34133241780000	METZNER 3	PORTAGE	-5233
34133241480000	TYMCIO 1	PORTAGE	-5238
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34133241830000	FLOWERS 2	PORTAGE	-5246
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34133240180000	MILLER # 1	PORTAGE	-5270
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34133240160000	MANHOLT UNIT 3	PORTAGE	-5276
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34133241610000	NEWHART-MILLER UNIT 4	PORTAGE	-5286
34133240330000	FOX W COMM #2 # 8489-001	PORTAGE	-5286
34133241240000	REED # RR1	PORTAGE	-5287
34133239790000	DANKO # 2	PORTAGE	-5287
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34133240200000	JENKINS # 1	PORTAGE	-5290
34133240120000	TIRE TREAD DEVELOPMENT COMM. #1 # 3691-0	PORTAGE	-5292
34133239830000	D & R D'AGOSTINE COMM #1 # 3562-001	PORTAGE	-5293
34133240240000	BROCKETT # 5	PORTAGE	-5297
34133241570000	KIRKLAND M & A COMM 1	PORTAGE	-5298
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34133240230000	BROCKETT # 4	PORTAGE	-5302
34133240170000	STOTLER 1	PORTAGE	-5303
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34133240990000	GROSSENBACHER UNIT 1	PORTAGE	-5305
34133239840000	DANKO # 3	PORTAGE	-5305
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34133236120000	MEREDITH UNIT # 1	PORTAGE	-5308
34133242210000	BAUMAN P 15	PORTAGE	-5308
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34133241340000	MINEAR UNIT 2	PORTAGE	-5312
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34133239920000	HOLLENDONNER 1	PORTAGE	-5316
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34133240890000	CRAMNER # 4-2304	PORTAGE	-5354
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34133241090000	M. SMITH #1 12119-01	PORTAGE	-5358
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34133241310000	RYAN UNIT 1	PORTAGE	-5363
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34133242750000	ENGLEHART 2	PORTAGE	-5380
34133242510000	FINEGAN UNIT 2	PORTAGE	-5381
34133242070000	PITTMAN 2	PORTAGE	-5383
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34133242140000	DEERFIELD FARMS R.R. 3	PORTAGE	-5389

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34133242310000	DEERFIELD FARMS 5	PORTAGE	-5400
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34133242390000	EDWARDS 1	PORTAGE	-5424
34133243040000	ABBE 5	PORTAGE	-5427
34133241590000	KOST T & M 1-RR	PORTAGE	-5444
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34133240730000	GAY # 2	PORTAGE	-5452
34133240840000	WOODS UNIT # 2	PORTAGE	-5459
34133242760000	MYERS G & L UNIT 1-RR	PORTAGE	-5489
34133244070000	PANDER UNIT 1	PORTAGE	-5491
34133241710000	SANDERS UNIT 2-K	PORTAGE	-5493
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34133240420000	SCOTT HEIRS UNIT #2	PORTAGE	-5507
34133242680000	SCOTT HEIRS 3	PORTAGE	-5508
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34151250150000	ZIMMER H & B 1	STARK	-4658
34151249700000	KIMMINS UNIT # 1	STARK	-4661
34151250600000	YODER UNIT # 1	STARK	-4670
34151249620000	DIGLAW E 2 # 8160-001	STARK	-4683
34151250910000	HAWK E & N 3	STARK	-4683
34151249850000	HERSHBERGER D & A UNIT # 1	STARK	-4700
34151253710000	WEISGARBER 2-K	STARK	-4702
34151250780000	BRENNER UNIT #2	STARK	-4702
34151253840000	BRUGH UNIT 1-K	STARK	-4702
34151249610000	RUEGG # 6	STARK	-4704
34151250590000	ROTTMAN 1	STARK	-4706
34151250500000	FAHRNI H & E COMMUNITY #1 # 12018-01	STARK	-4707
34151249710000	WHEELING & LAKE ERIE RR #1 # 8482-001	STARK	-4711

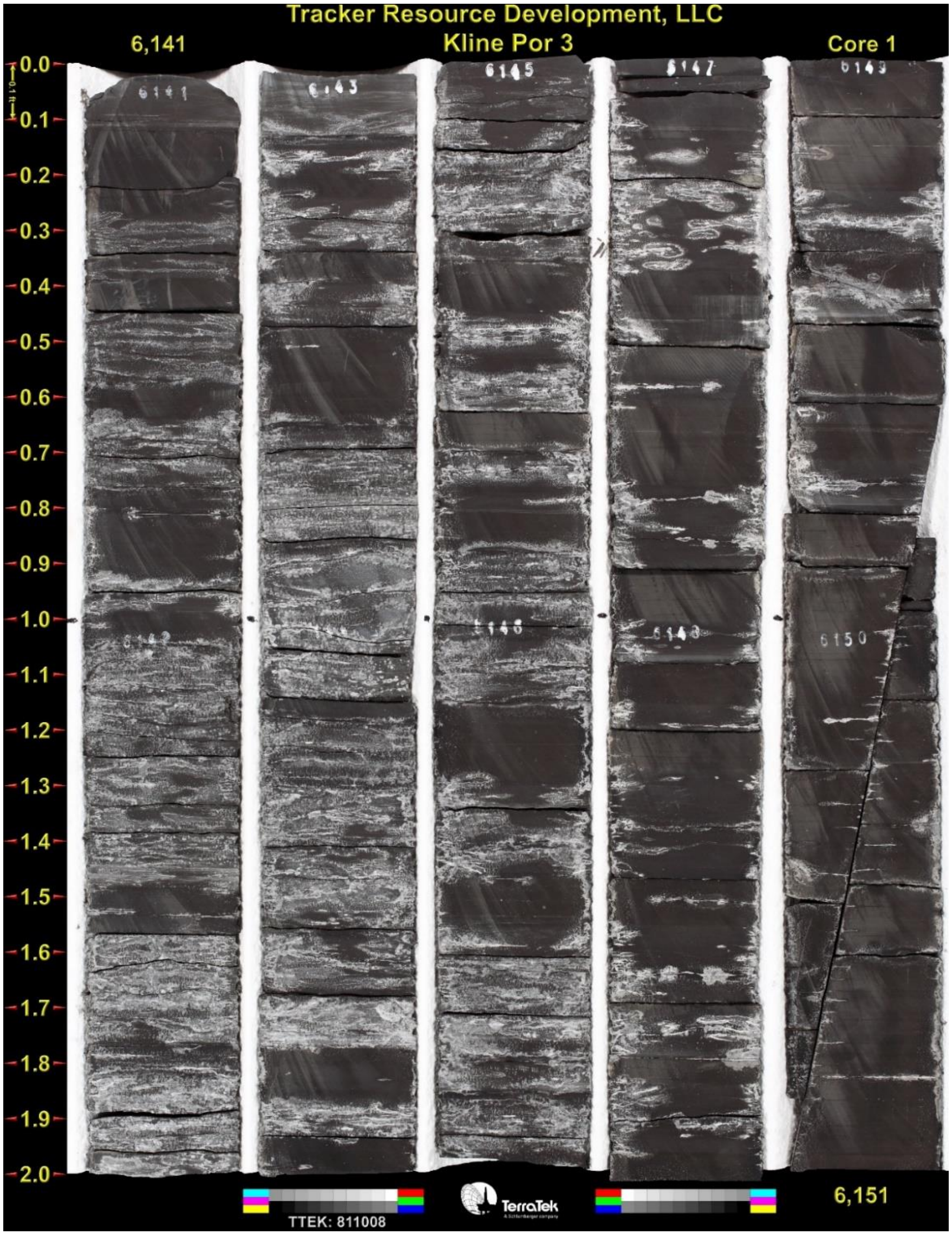
34151249380000	D. & M. HUFF #2 # 3836-001	STARK	-4713
34151255460000	BREWSTER MOBILE HOMES 3	STARK	-4716
34151252530000	N & W RAILROAD 7	STARK	-4723
34151249140000	P. SOEHNLEN # 1-78	STARK	-4725
34151250110000	POLAND UNIT # 1-99	STARK	-4734
34151246010000	N. & W. RAILROAD #5 # 5	STARK	-4735
34151248320000	STARK WILDERNESS # 2	STARK	-4736
34151250160000	VAUGHN UNIT #2-K	STARK	-4746
34151250770000	WILSON-HERSHBERGER UNIT #4-K	STARK	-4748
34151250440000	WILSON-HERSHBERGER UNIT #3-K	STARK	-4751
34151246000000	N. & W. RAILROAD 6	STARK	-4751
34151257750000	MAJORS 1	STARK	-4755
34151250640000	STAHL V COMMUNITY #1	STARK	-4766
34151250080000	FEICHTER M UNIT 1	STARK	-4768
34151250070000	WALKER A # 3-8842	STARK	-4770
34151249160000	G & J GRABILL COMM #1 # 3800-001	STARK	-4772
34151250130000	J. CLAY UNIT # 1	STARK	-4777
34151257550000	DC ROHR #1A A	STARK	-4779
34151248740000	G & L MARCHAND COMM 3-3492	STARK	-4780
34151248190000	W & C BUCHER COMM. #3 # 3473-001	STARK	-4783
34151258140000	HAMMER 1-K	STARK	-4784
34151250630000	WENTLING W & H COMM 2	STARK	-4785
34151250020000	WEFLER W # 8-11918	STARK	-4785
34151250790000	BOWMAN D ET AL COMM 3	STARK	-4790
34151249920000	W & A SMITH #2-K	STARK	-4791
34151249910000	INDORF D & M COMMUNITY # 3-11907	STARK	-4793
34151243260000	R. G. EBERHARDT # 1-342704	STARK	-4807
34151249990000	EBERHARDT O. COMM. 2-11916	STARK	-4810
34151250560000	ROHR E 2	STARK	-4820
34151252680000	HENSEL UNIT 5-K	STARK	-4821
34151250570000	ROHR 1	STARK	-4821
34151251330000	DUTTON UNIT 1-32	STARK	-4823
34151250120000	CHARTERS # 1-25	STARK	-4827
34151246660000	E. & M. HARROLD #2 # 3369-001	STARK	-4829
34151249650000	MAUGER #2 8161-001-00	STARK	-4829
34151249660000	GROVE # 1-K	STARK	-4832
34151248200000	WEIRICH 1-3472	STARK	-4836
34151251160000	P&V LAUTZENHEISER #U #2-K	STARK	-4838
34151245270000	W & H KEGLEY COMMUNITY # 1-3223	STARK	-4839

34151251020000	BONANNO J COMMUNITY #1 12424-001-00	STARK	-4839
34151250540000	DRAKE T 1	STARK	-4846
34151246310000	M. & L. KEIM ETAL #1 # 3308-001	STARK	-4846
34151246980000	COURTNEY R & K COMM 1-3430	STARK	-4850
34151246370000	WOOD J ETAL COMM. 1 3318-001	STARK	-4854
34151250980000	CLEANERS HANGER 2-A	STARK	-4854
34151251830000	DURISHIN UNIT 1-K	STARK	-4856
34151246970000	E. & M. HARROLD #3 # 3409-001	STARK	-4864
34151248140000	B & D LANDIS COMM 2	STARK	-4865
34151245060000	INDORF D & M COMM. 2-3198-001	STARK	-4868
34151247350000	M. HARROLD COMM. #1A # 3408-001	STARK	-4873
34151246830000	J. WEBER # 2	STARK	-4875
34151251140000	FOSTER F COMM 2	STARK	-4875
34151245190000	A. RUEGG # 2-3210	STARK	-4880
34151245080000	G. ROHN # 1-A	STARK	-4884
34151248100000	EBERLY UNIT # 1	STARK	-4885
34151252030000	NOFSINGER LOTTIE 2-K	STARK	-4901
34151254750000	PSR 1	STARK	-4902
34151256810000	KEM 1	STARK	-4904
34151246670000	RUSSELL BALTZLY #4 # 3370-001	STARK	-4908
34151251510000	CARLONE UNIT 1	STARK	-4909
34151246300000	A. RUEGG ETAL #3 # 3306-001	STARK	-4913
34151249110000	G THOMAS UNIT #3-K-PLUG 5/98	STARK	-4913
34151256600000	PSR 5	STARK	-4917
34151227760000	R & I HARTLINE COMM #1D # 804-001	STARK	-4918
34151256110000	NFMWE 1	STARK	-4930
34151256800000	PSR 6	STARK	-4942
34151246330000	T. EDDY COMMUNITY #2 # 3316-001	STARK	-4944
34151251480000	SCHALMO UNIT 1-K	STARK	-4974
34151258780000	JIM KLICK 2	STARK	-5039
34151246360000	D. FRITZ #1 # 3320-001	STARK	-5053
34151245370000	E. J. PLOTT & CO. INC. # 1-3224	STARK	-5102
34151251690000	MIHALIK T&S 1-12 539	STARK	-5106
34151254310000	DUERR R & E UNIT 2-K	STARK	-5151
34151245070000	JOHN'S SPORTING GOODS INC. # 1-3197	STARK	-5197
34151258250000	MILLER W & M 4-K	STARK	-5284
34151251770000	A & C RAINIERI COMM 1	STARK	-5285
34151250250000	VAUGHAN K & D COMMUNITY # 4-11980	STARK	-5288
34151258840000	KAKISH UNIT 1-K	STARK	-5297

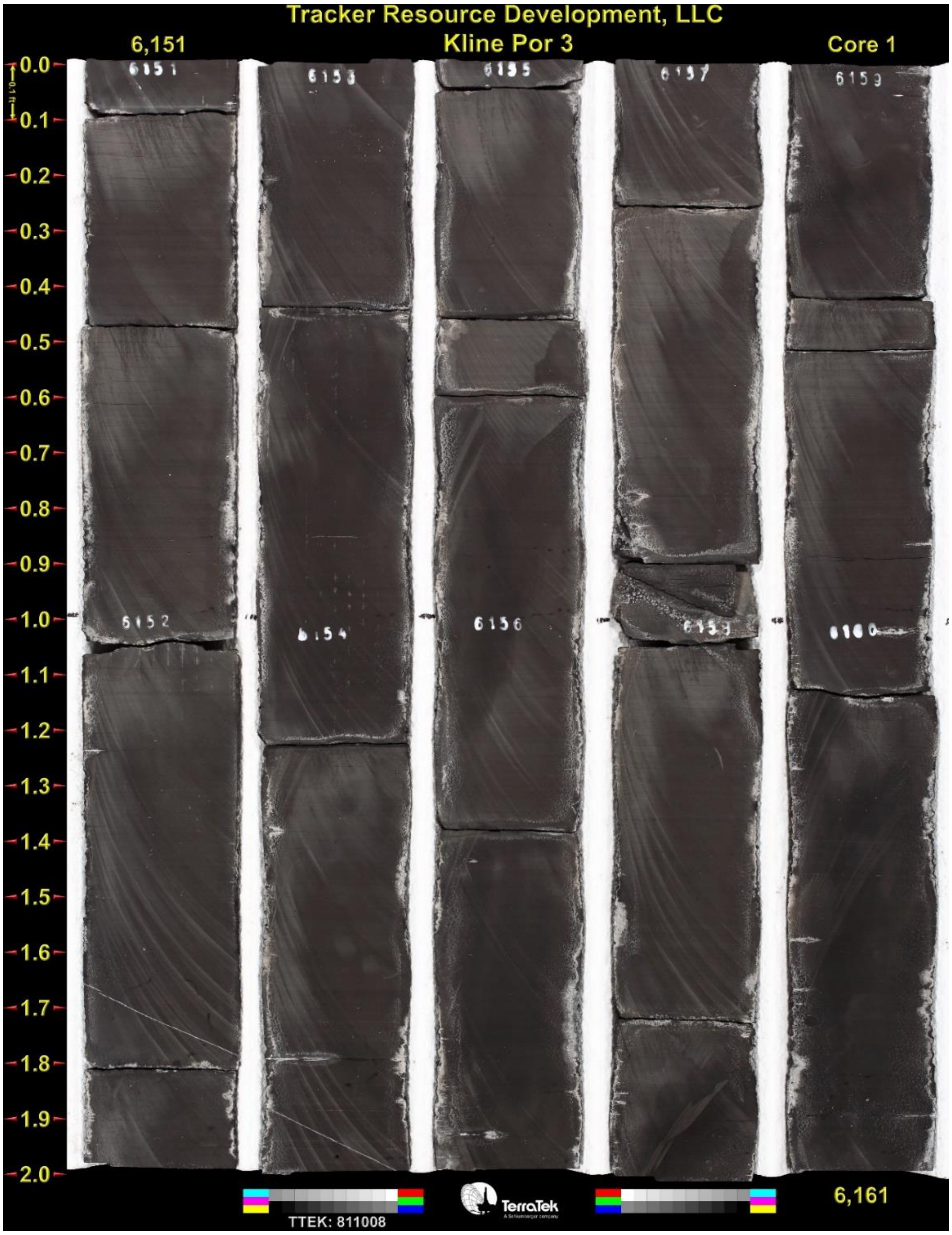
34151258830000	BURNS UNIT 1-K	STARK	-5298
34151258820000	RUFENERS CONGRESS LAKE UNIT 1-K	STARK	-5305
34151255330000	VAUGHN UNIT ETAL 1A	STARK	-5308
34151257190000	R & E KRABILL UNIT 1-K	STARK	-5315
34151257990000	VAUGHAN UNIT 2-K	STARK	-5315
34151250890000	WOLF I COMMUNITY 2	STARK	-5317
34151258400000	TESSMER H & M UNIT 1-K	STARK	-5317
34151258240000	MILLER O & K 2-K	STARK	-5319
34151257620000	KIKO UNIT 1-K	STARK	-5322
34151252280000	STROUBLE COMM A & L 5	STARK	-5324
34151258190000	KIKO 2-K	STARK	-5327
34151250260000	WOLF E & R COMMUNITY 1	STARK	-5328
34151258560000	H & H PROPERTIES 1-K	STARK	-5338
34151256300000	REEVES UNIT 3	STARK	-5339
34151248910000	WEISANT C & J COMM 2	STARK	-5345
34151258430000	MOORE H & L UNIT 1-K	STARK	-5350
34151252430000	BINGHAM 3-K	STARK	-5378
34151252300000	PONTIUS UNIT 1-K	STARK	-5379
34151247510000	LOUISE BINGHAM & RALPH BINGHAM # 1	STARK	-5384
34151250950000	MCCARTY G & B COMM #1 12290-001-00	STARK	-5386
34151257930000	ZUMKEHR 2-K	STARK	-5386
34151257890000	ROYER M & C 7-K	STARK	-5403
34151251310000	FOX 1-A	STARK	-5411
34151250880000	DUFF J. COMM. #1 12240	STARK	-5417
34151249150000	JAMES MCCANN UNIT # 1	STARK	-5423
34151257000000	SCHNASE COMMUNITY 3	STARK	-5433
34151251010000	BINGHAM UNIT 1-K	STARK	-5435
34151251520000	BINGHAM 1	STARK	-5440
34151250210000	S. SZEKELY COMM 2	STARK	-5440
34151251070000	BINGHAM UNIT #2-K	STARK	-5441
34151252290000	WITTE UNIT 4-K	STARK	-5441
34151251490000	FOX UNIT 2	STARK	-5443
34151251460000	WEISENT 33	STARK	-5448
34151251340000	KAPPER 1	STARK	-5450
34151251430000	KAPPER 3	STARK	-5456
34151251280000	LINERODE 1-2941	STARK	-5457
34151252340000	SLABACH UNIT 1-K	STARK	-5474
34151251500000	LINERODE 3-2943	STARK	-5475
34151250050000	WITTE UNIT #3-K	STARK	-5476

34151251730000	KLODT UNIT 1-2982	STARK	-5482
34151251890000	HAGAN UNIT 2-K	STARK	-5491
34151251270000	LINERODE 2-2942	STARK	-5507
34151251870000	CITY OF ALLIANCE 3-2986	STARK	-5510
34151249280000	MACARIE 4	STARK	-5512
34151251880000	CITY OF ALLIANCE 2-2985	STARK	-5513
34151248170000	P. MACARIE # 3	STARK	-5514
34151252380000	MILLER WILLIAM UNIT 1-K	STARK	-5519
34151252840000	THORNBERRY UNIT 1-K	STARK	-5521
34151228770000	REED 1	STARK	-5536
34151252210000	CLAPSADDLE UNIT 1-K	STARK	-5536
34151252400000	MONTGOMERY UNIT 2-K	STARK	-5549
34151253610000	WALKER JOHN UNIT 1-K	STARK	-5550
34151253000000	ROBINSON G UNIT 1-K	STARK	-5559
34151252750000	FRANK D & T 1-K	STARK	-5563
34151252910000	HAZEN UNIT 1-K	STARK	-5605
34151250030000	SICKAFOOSE # 1-D	STARK	-5620
34151250860000	BARLEY 1-2397	STARK	-5643
34151257470000	DREVON 29-18-7 8	STARK	-5649
34151257670000	PARADISE VALLEY FARMS 17-18-6 8	STARK	-5730
34151250850000	TANNER UNIT 1	STARK	-5816
34151250680000	YODER UNIT 2	STARK	-5831
34151251550000	STONEHILL 4	STARK	-5866
34151235810000	STONEHILL 2	STARK	-5883
34151250060000	BELKNAP # 2	STARK	-5933
34151257740000	SMITH RONALD 3-17-6 3	STARK	-5958
34151249780000	BELKNAP-SLAGEL UNIT # 1	STARK	-6030
34151250520000	HANNA UNIT # 1	STARK	-6048

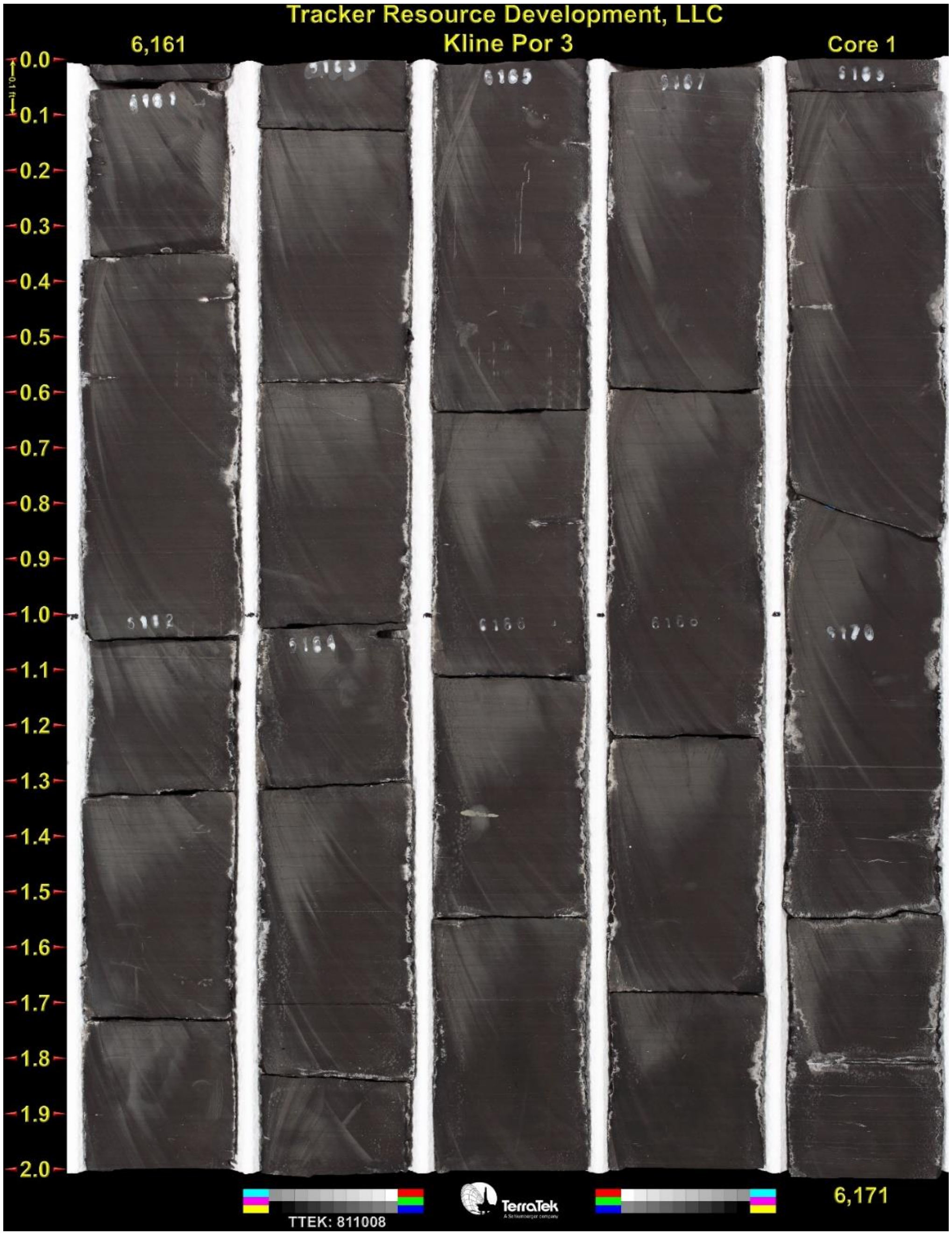
Appendix 4 – Slab packed core sample pictures with depth values in feet.



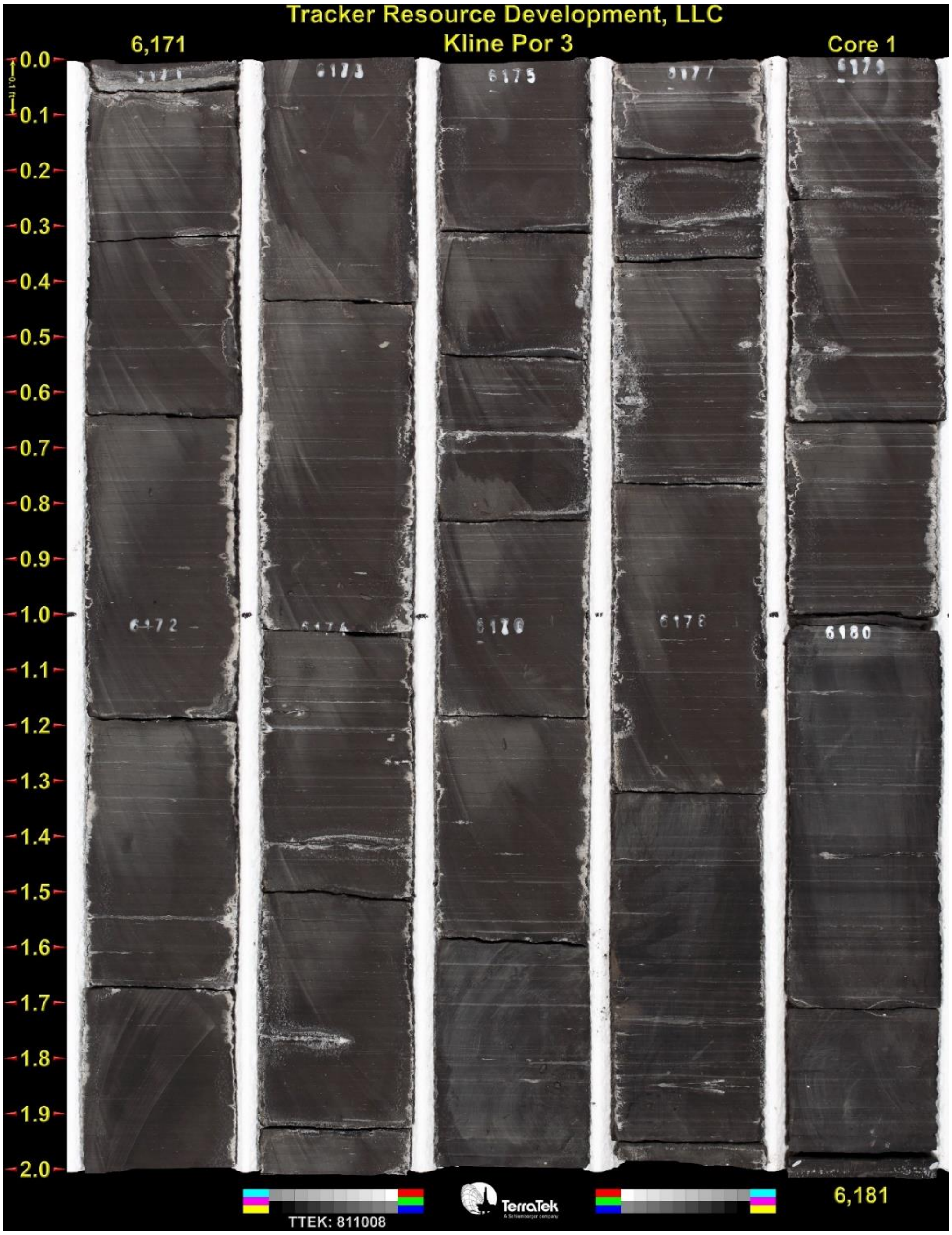
Slab pack core sample of Kline Por 3 well in Portage County, Ohio. Interval is 6,141-6,151 feet. Photos taken by Terra Tek.



Slab pack core sample of Kline Por 3 well in Portage County, Ohio. Interval is 6,151-6,161 feet. Photos taken by Terra Tek.

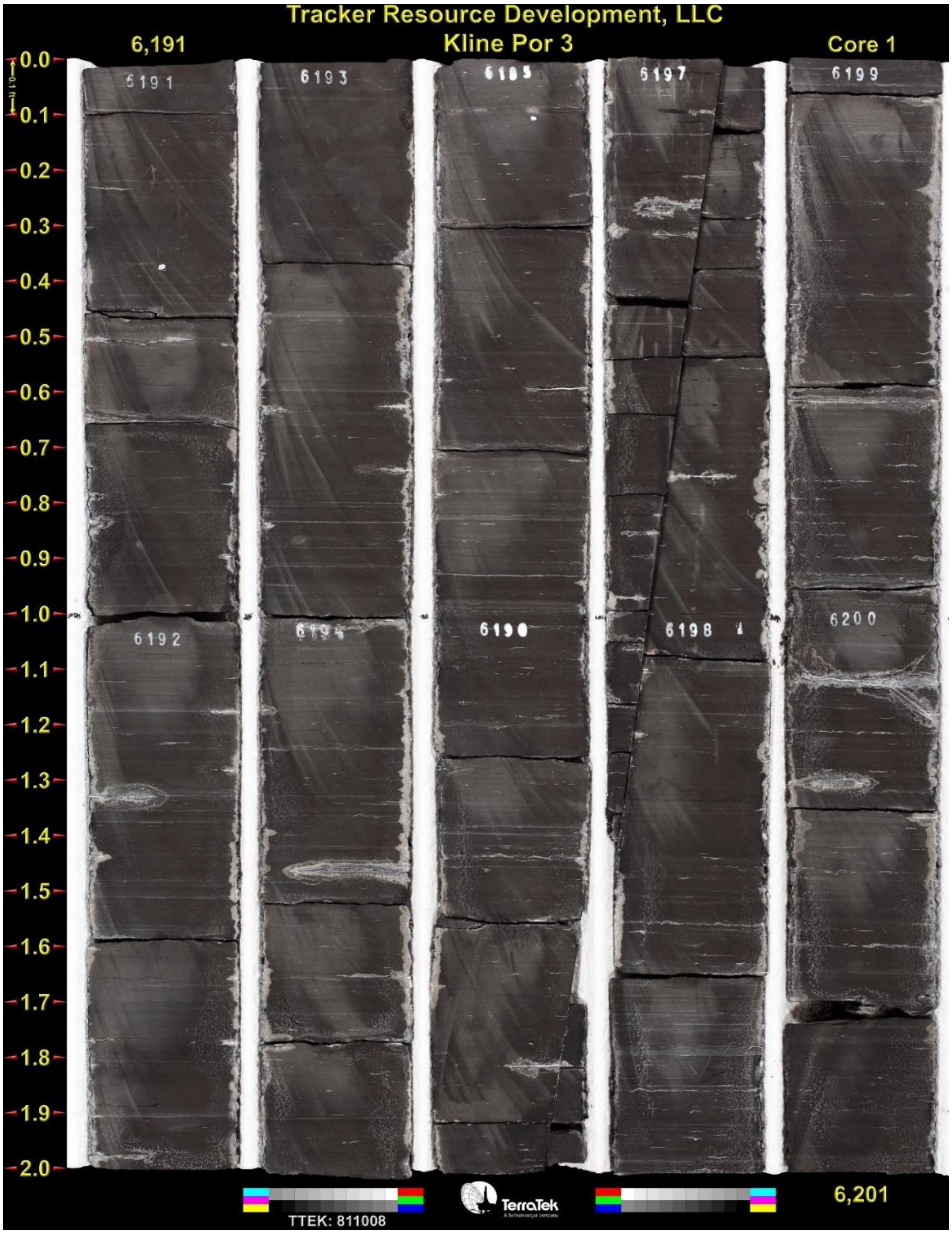


Slab pack core sample of Kline Por 3 well in Portage County, Ohio. Interval is 6,161-6,171 feet. Photos taken by Terra Tek.

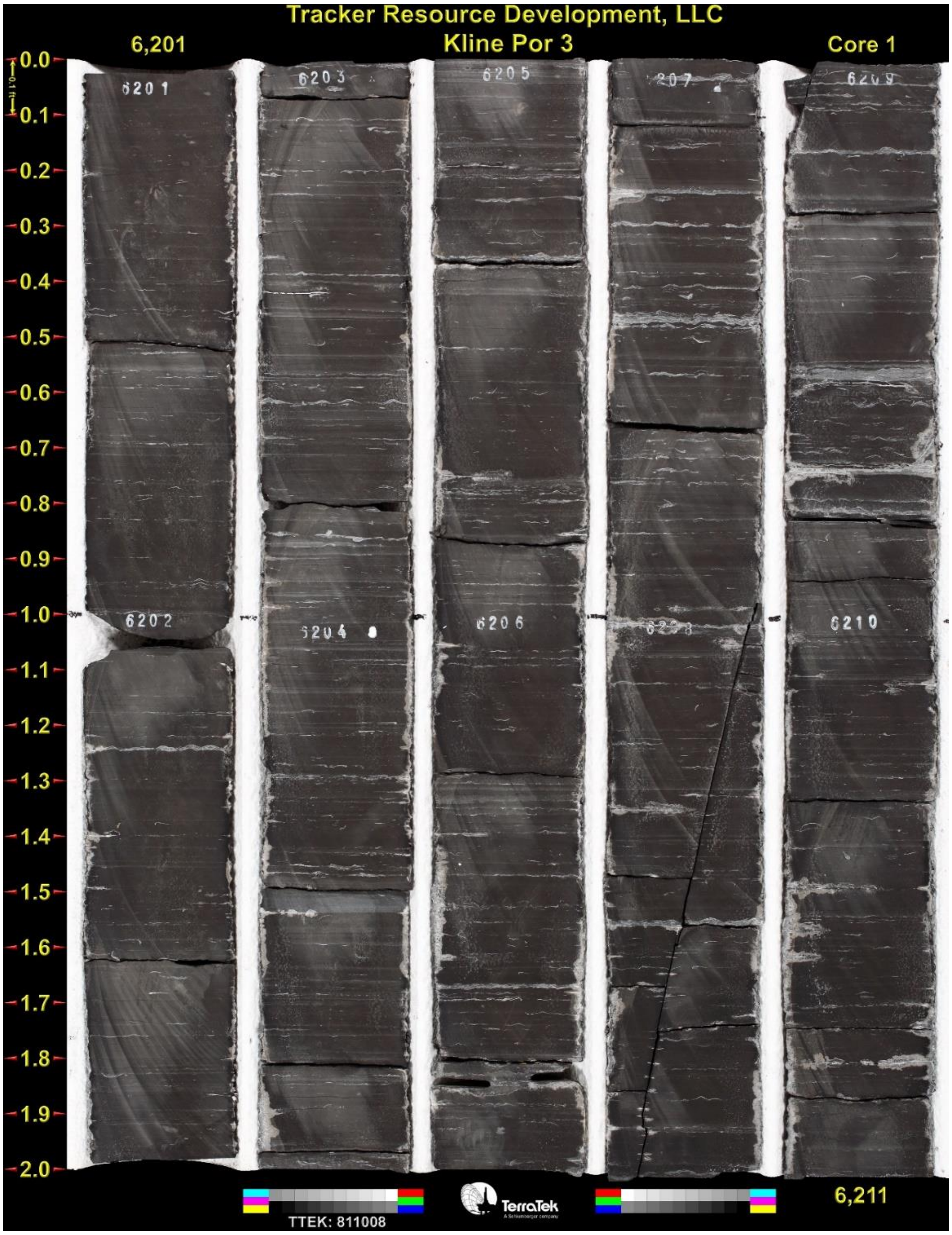


Slab pack core sample of Kline Por 3 well in Portage County, Ohio. Interval is 6,171-6,181 feet. Photos taken by Terra Tek.

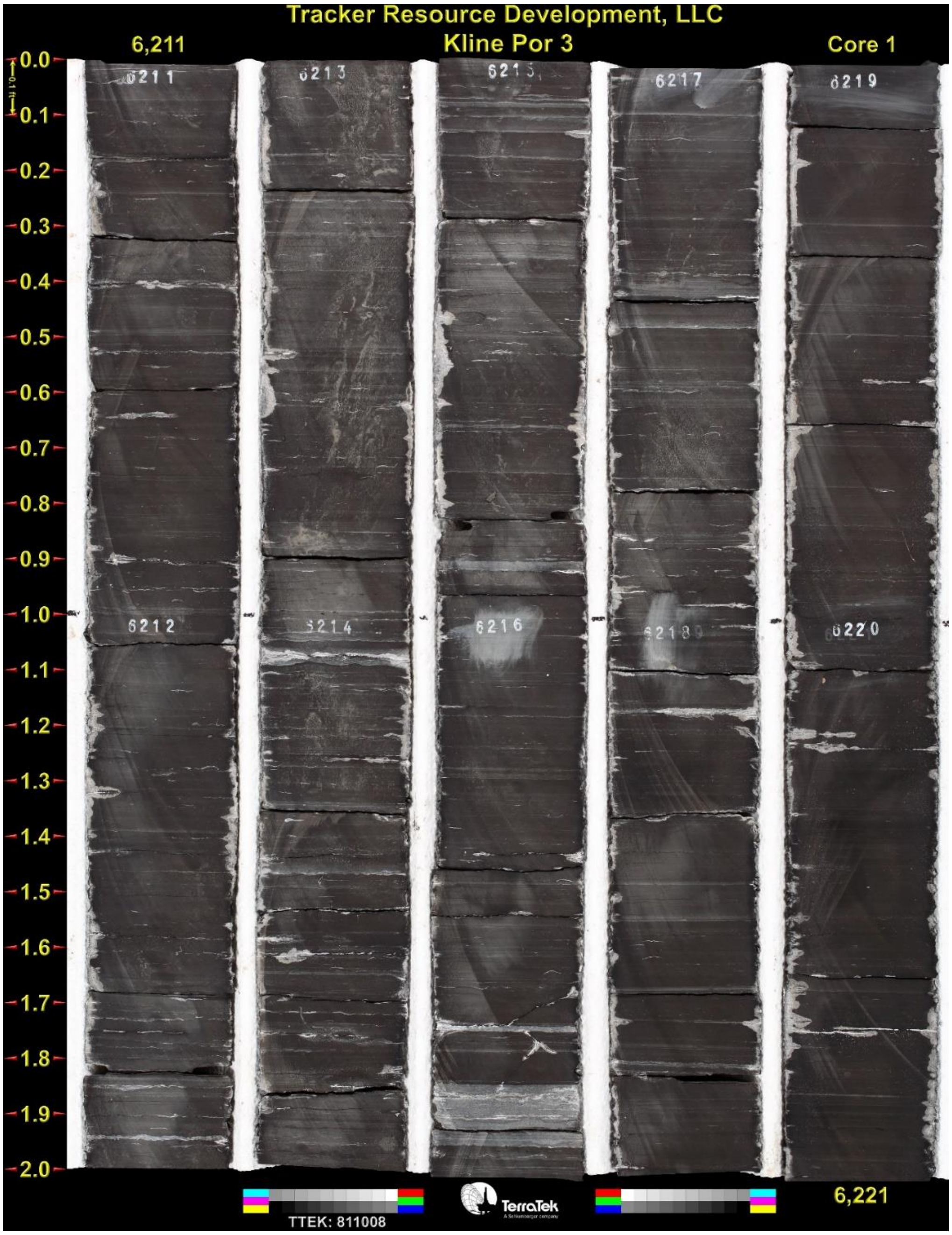
Slab pack core sample of Kline Por 3 well in Portage County, Ohio. Interval is 6,181-6,191 feet. Photos taken by Terra Tek.



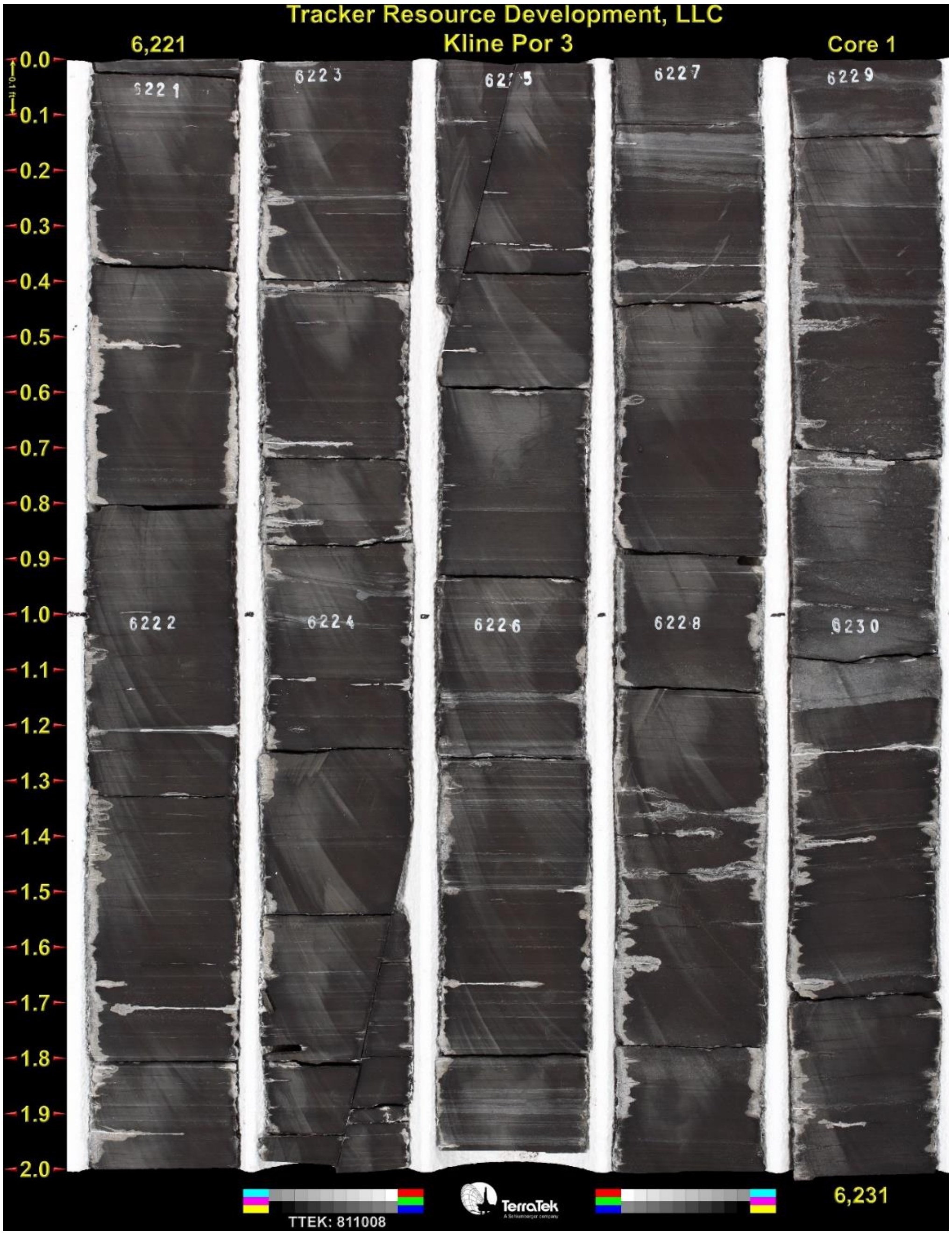
Slab pack core sample of Kline Por 3 well in Portage County, Ohio. Interval is 6,191-6,201 feet. Photos taken by Terra Tek.



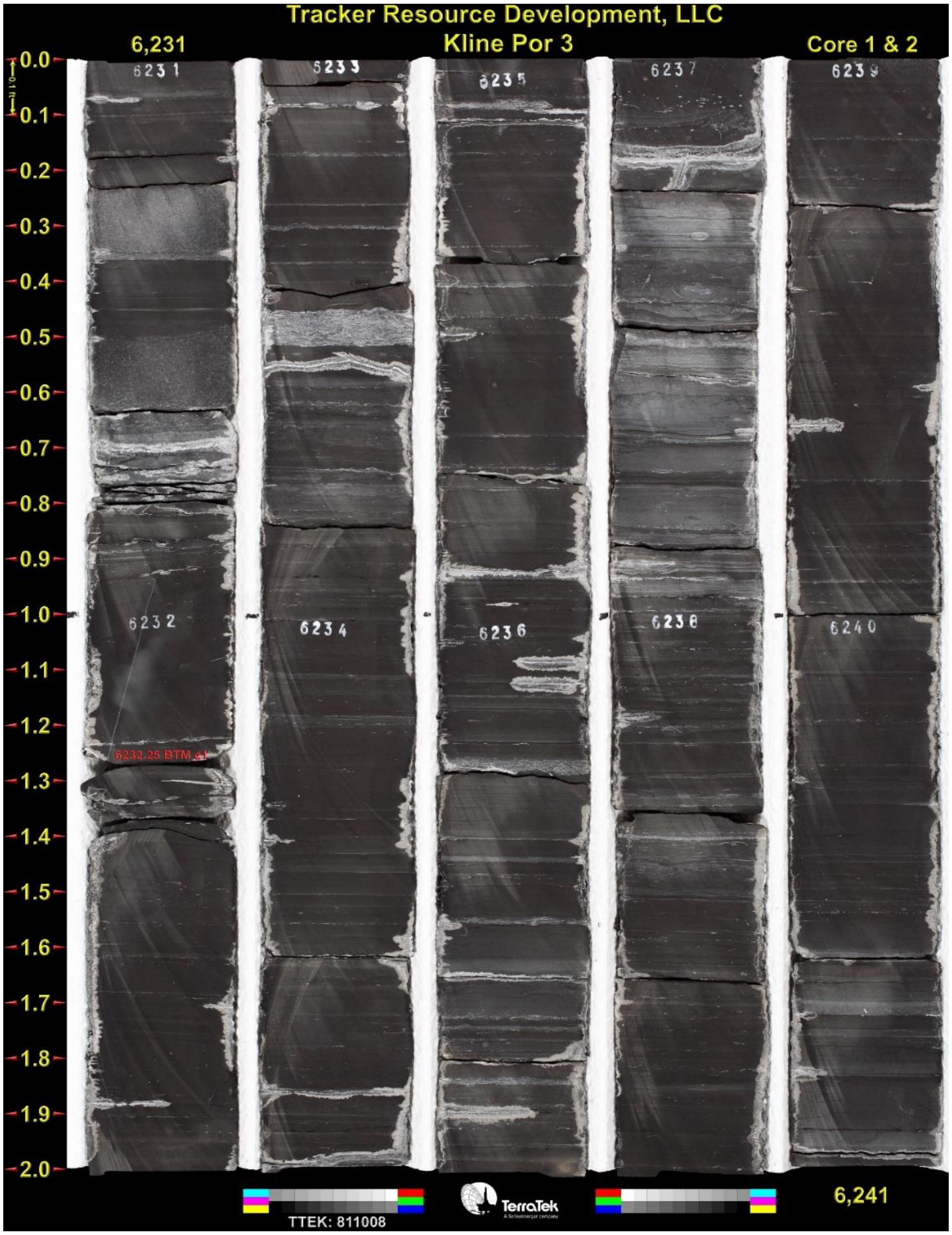
Slab pack core sample of Kline Por 3 well in Portage County, Ohio. Interval is 6,201-6,211 feet. Photos taken by Terra Tek.



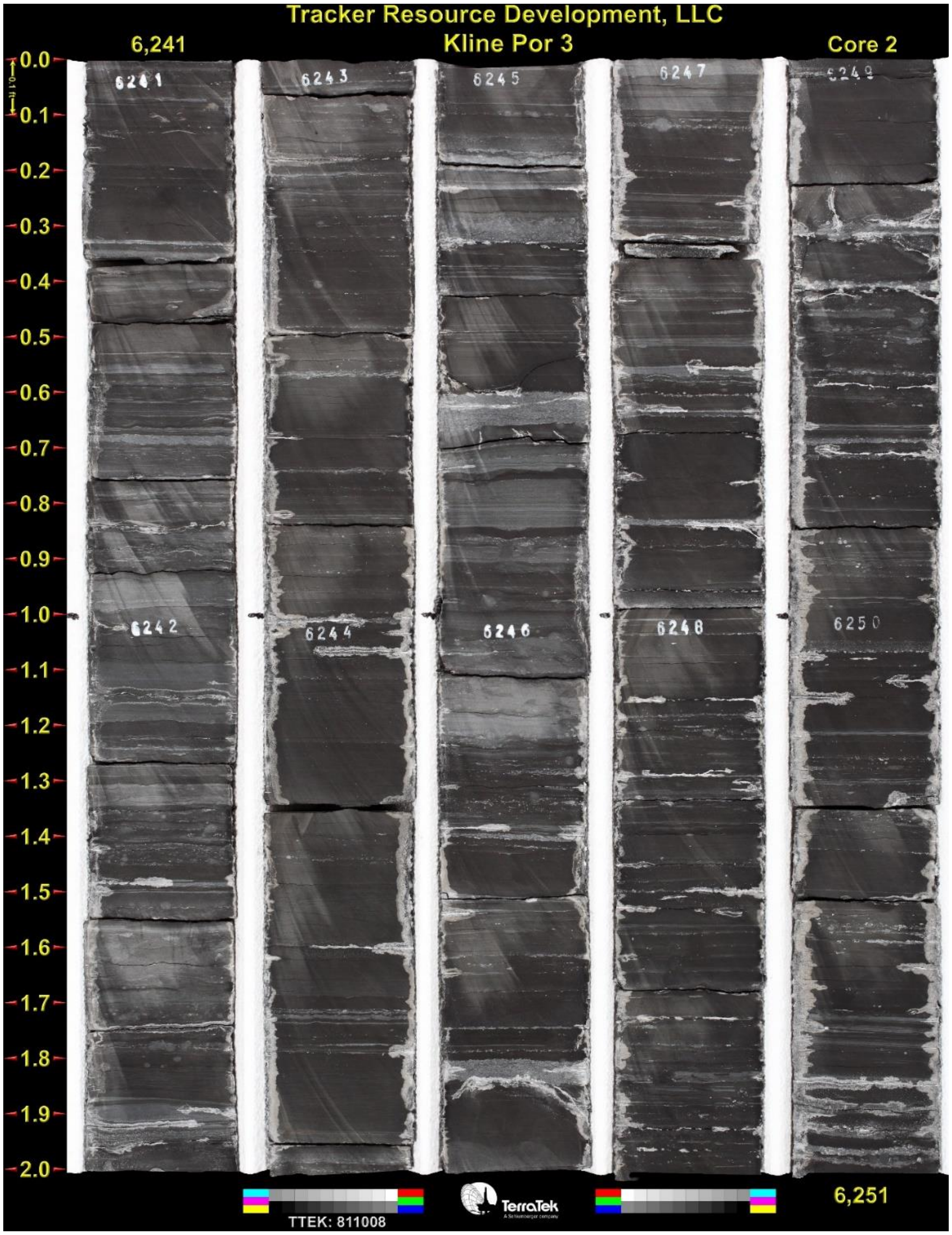
Slab pack core sample of Kline Por 3 well in Portage County, Ohio. Interval is 6,211-6,221 feet. Photos taken by Terra Tek.



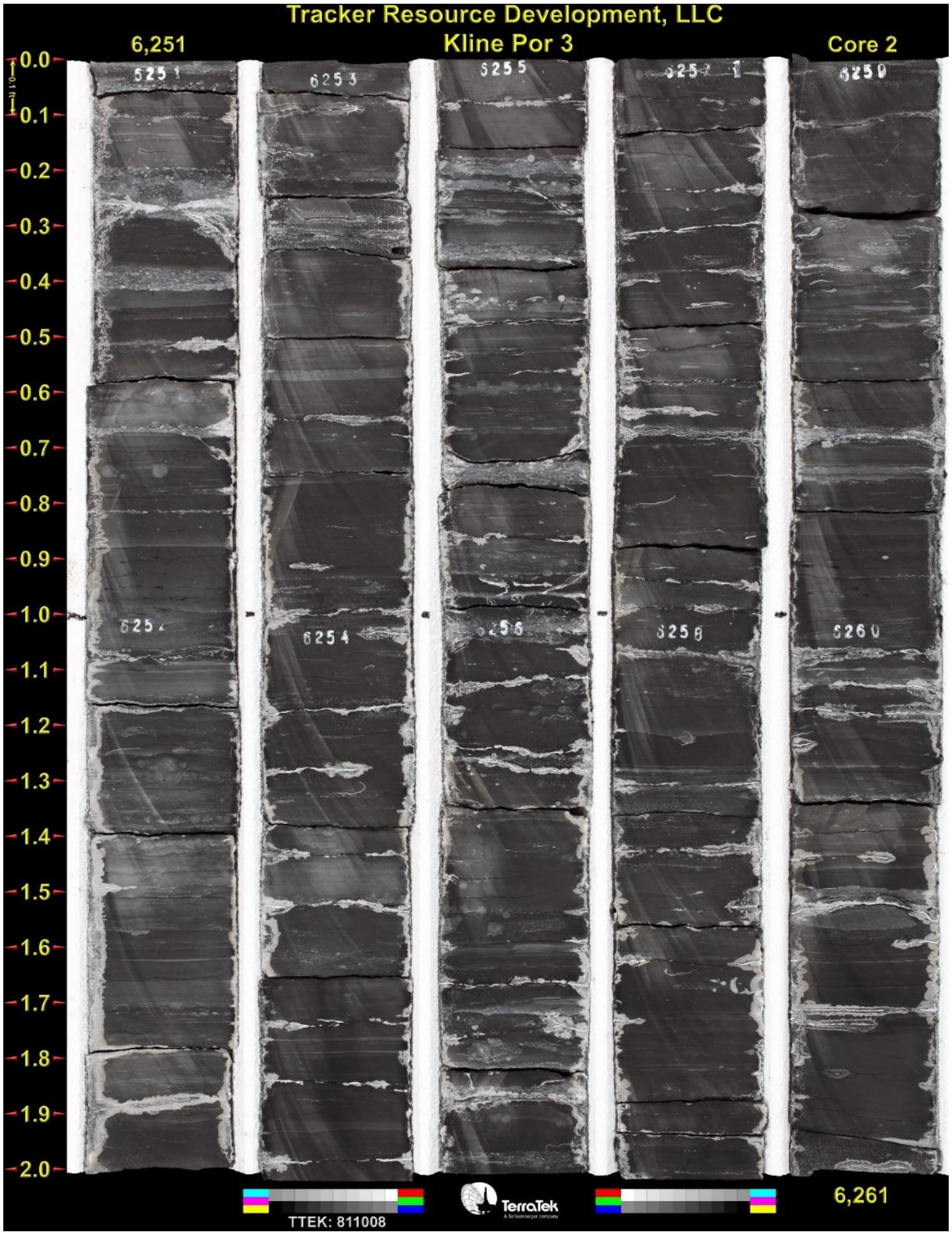
Slab pack core sample of Kline Por 3 well in Portage County, Ohio. Interval is 6,221-6,231 feet. Photos taken by Terra Tek.



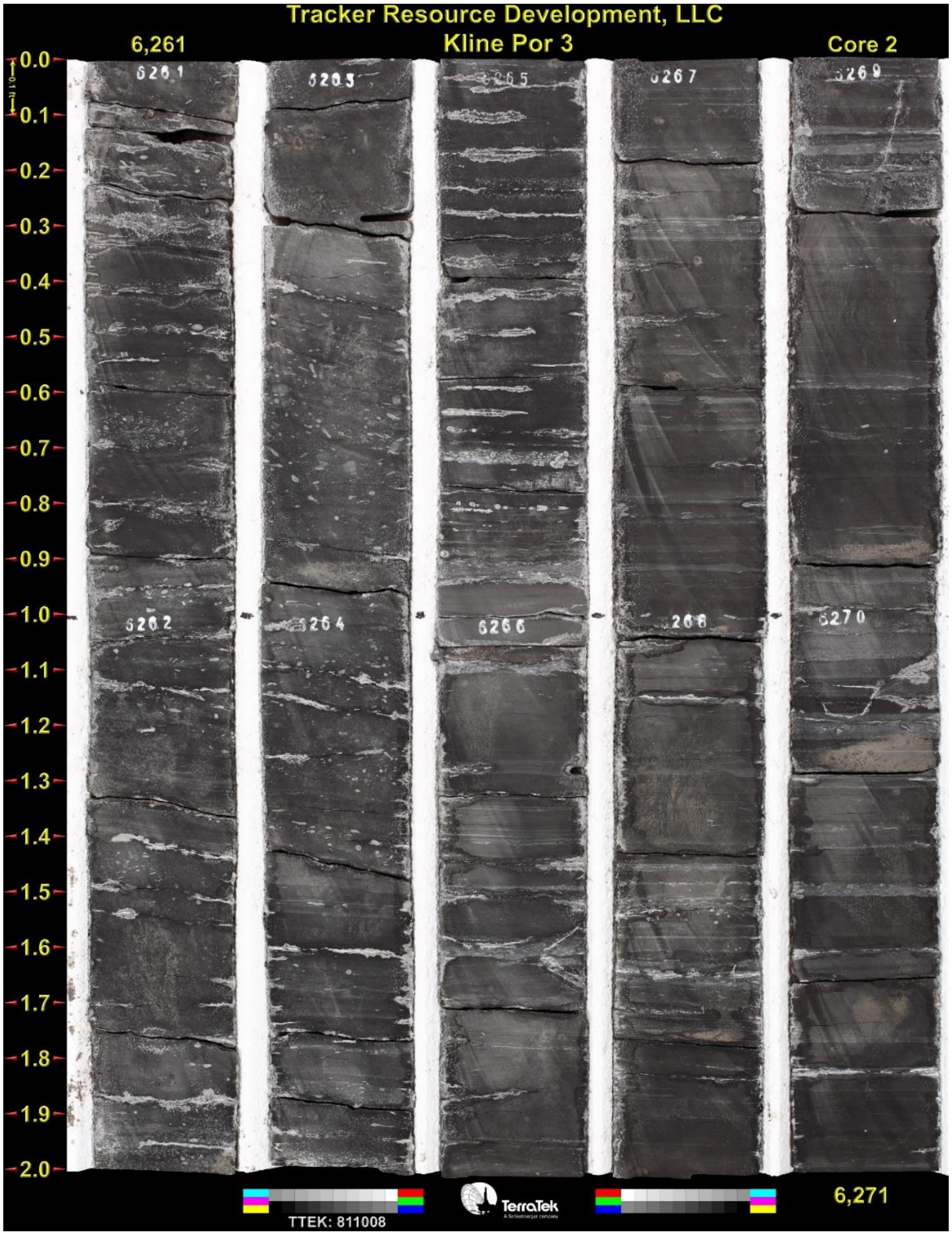
Slab pack core sample of Kline Por 3 well in Portage County, Ohio. Interval is 6,231-6,241 feet. Photos taken by Terra Tek.



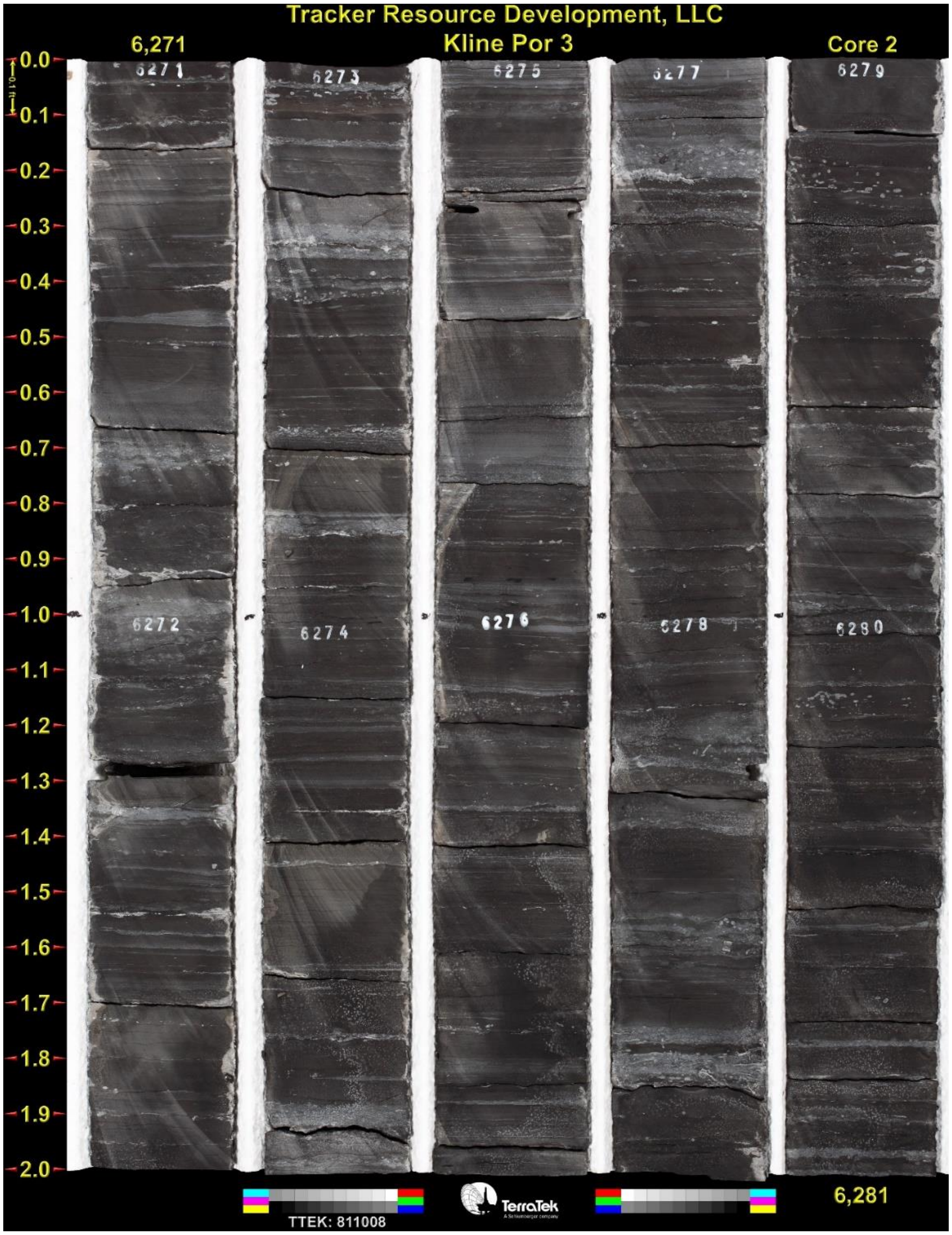
Slab pack core sample of Kline Por 3 well in Portage County, Ohio. Interval is 6,241-6,251 feet. Photos taken by Terra Tek.



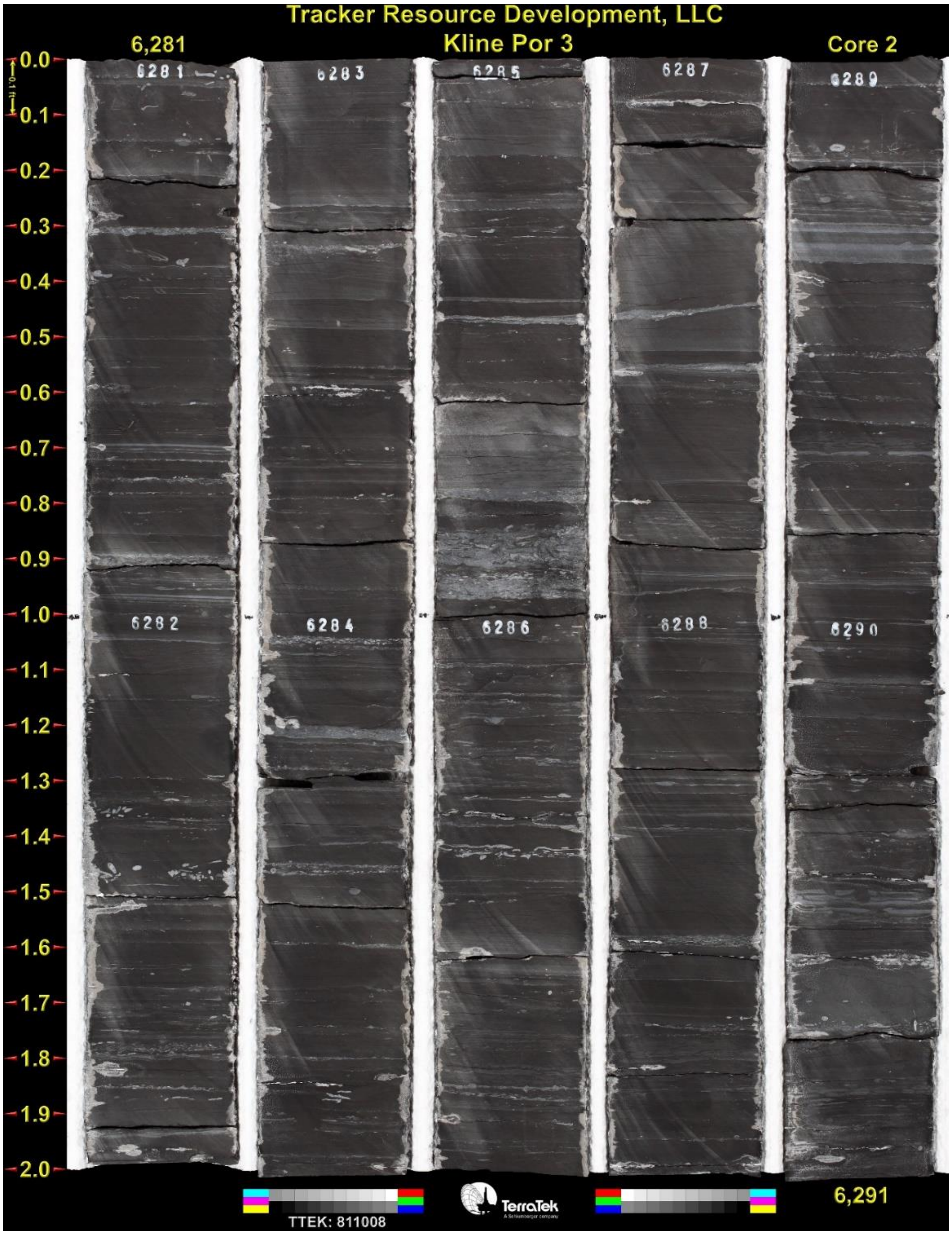
Slab pack core sample of Kline Por 3 well in Portage County, Ohio. Interval is 6,251-6,261 feet. Photos taken by Terra Tek.



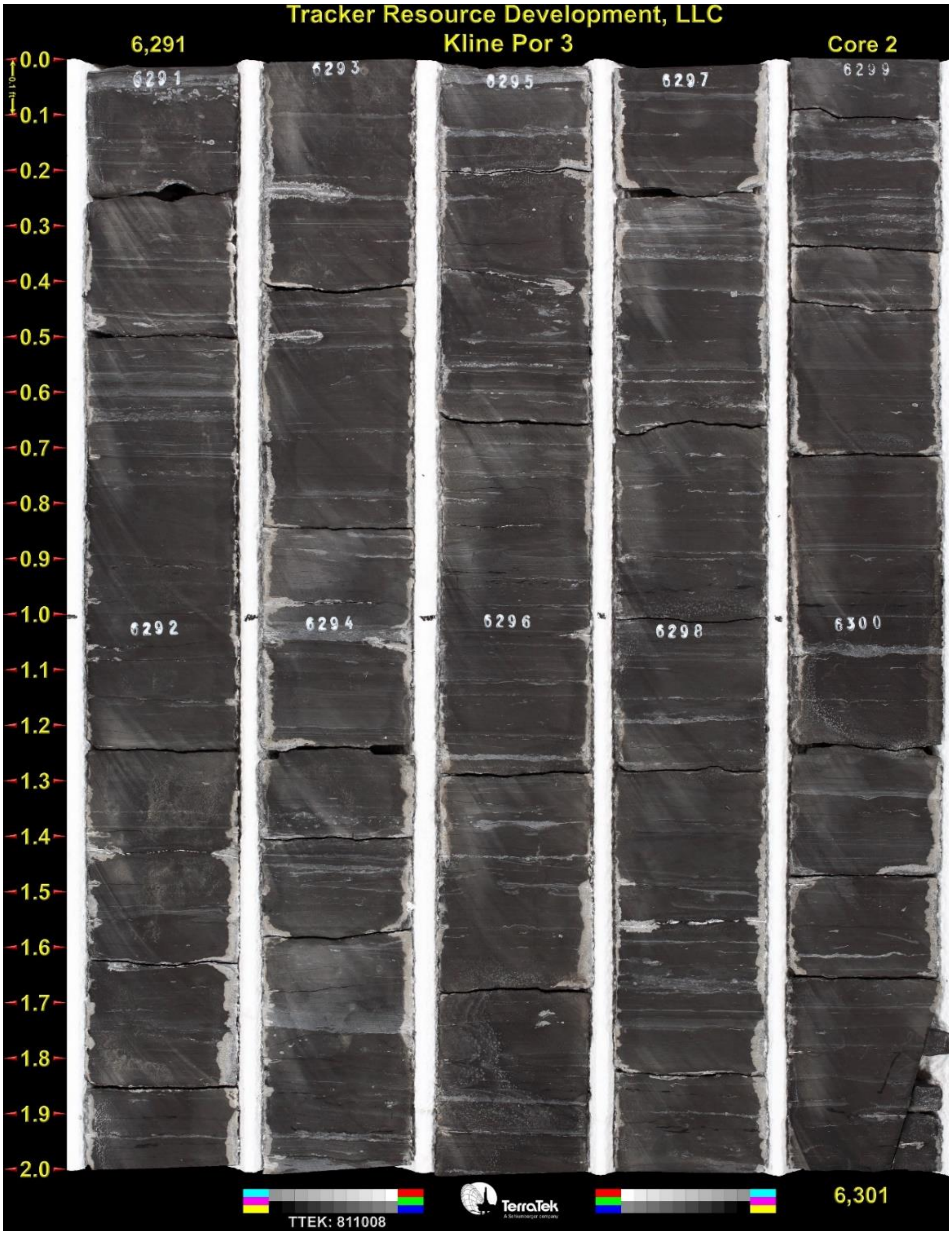
Slab pack core sample of Kline Por 3 well in Portage County, Ohio. Interval is 6,261-6,271 feet. Photos taken by Terra Tek.



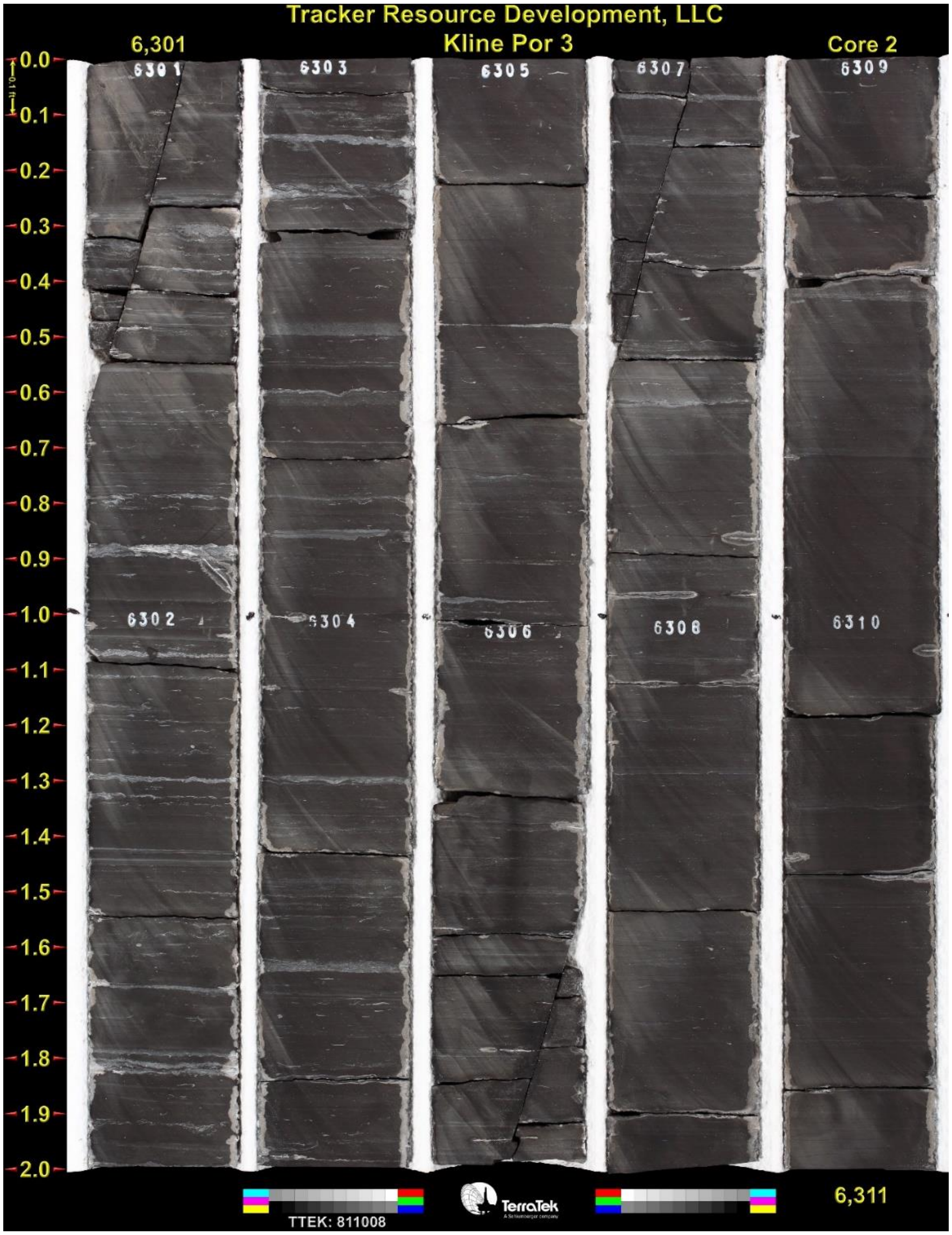
Slab pack core sample of Kline Por 3 well in Portage County, Ohio. Interval is 6,271-6,281 feet. Photos taken by Terra Tek.



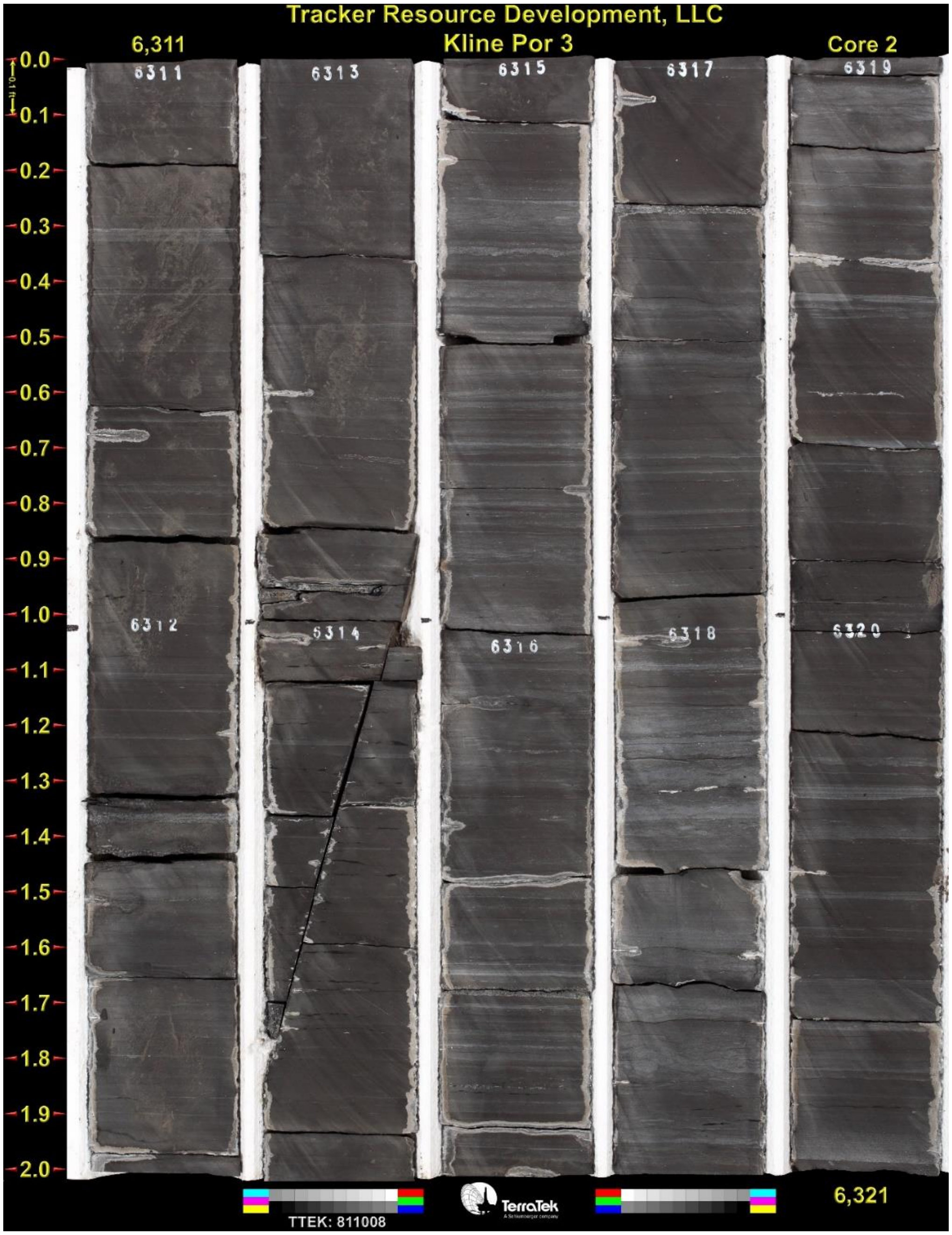
Slab pack core sample of Kline Por 3 well in Portage County, Ohio. Interval is 6,281-6,291 feet. Photos taken by Terra Tek.



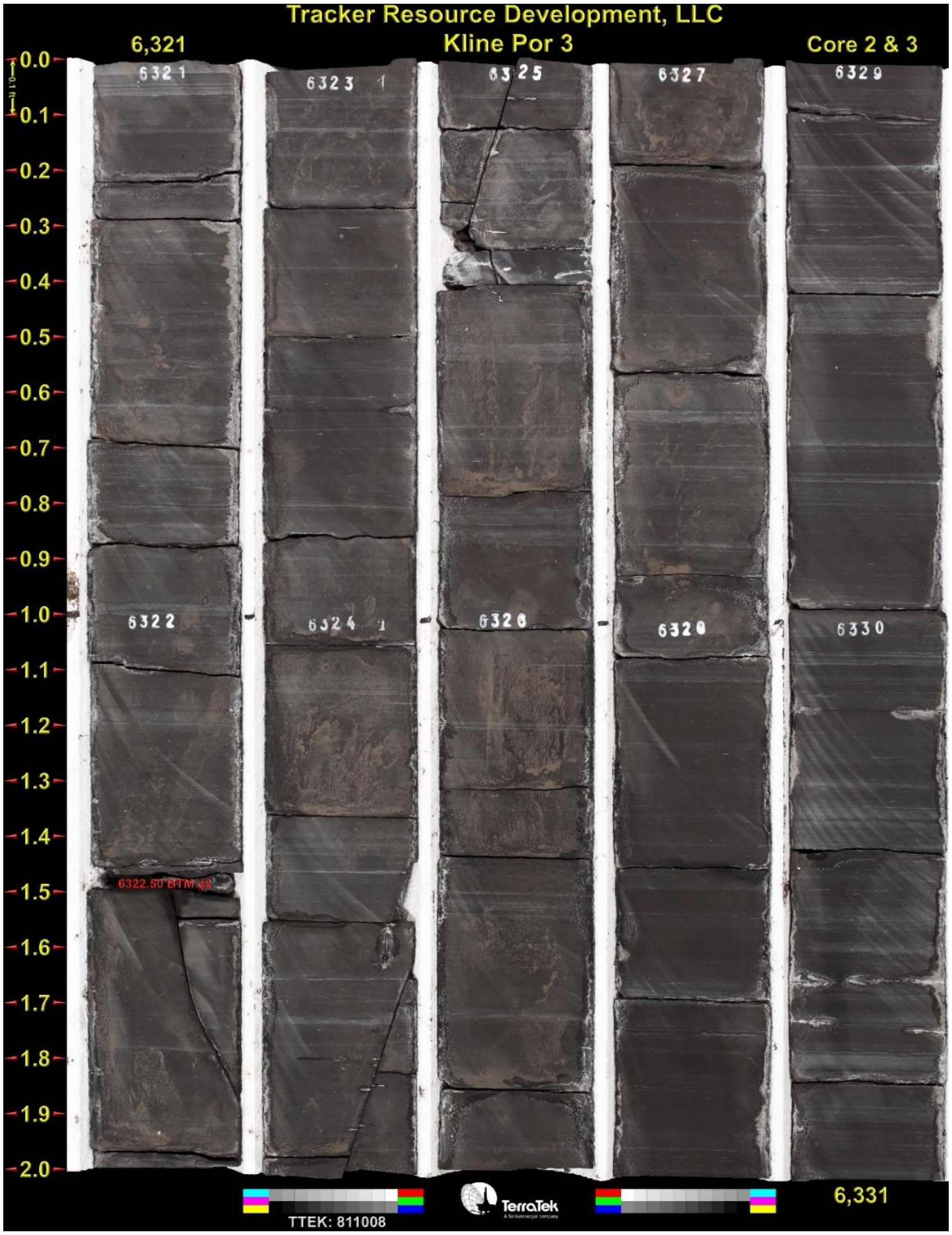
Slab pack core sample of Kline Por 3 well in Portage County, Ohio. Interval is 6,291-6,301 feet. Photos taken by Terra Tek.



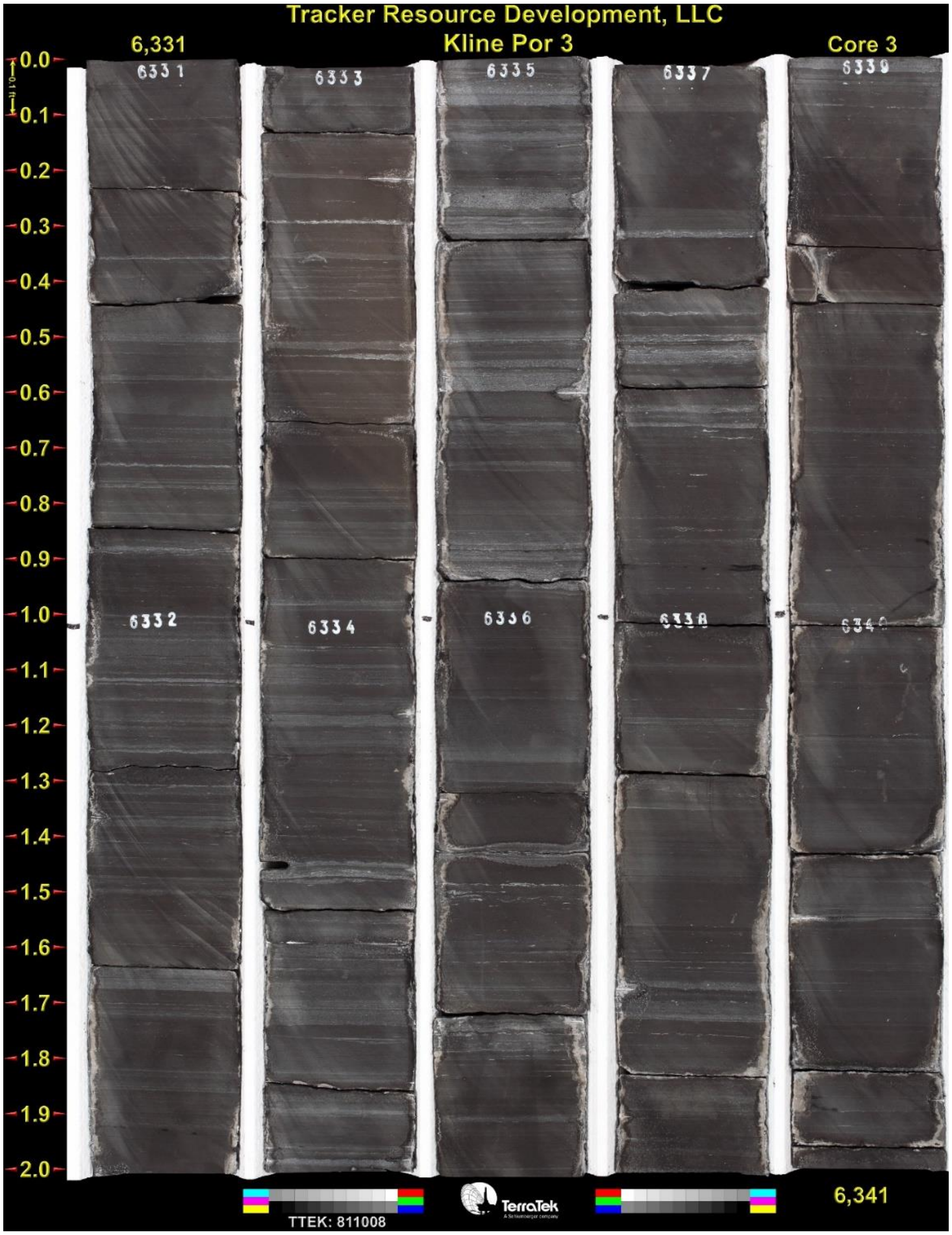
Slab pack core sample of Kline Por 3 well in Portage County, Ohio. Interval is 6,301-6,311 feet. Photos taken by Terra Tek.



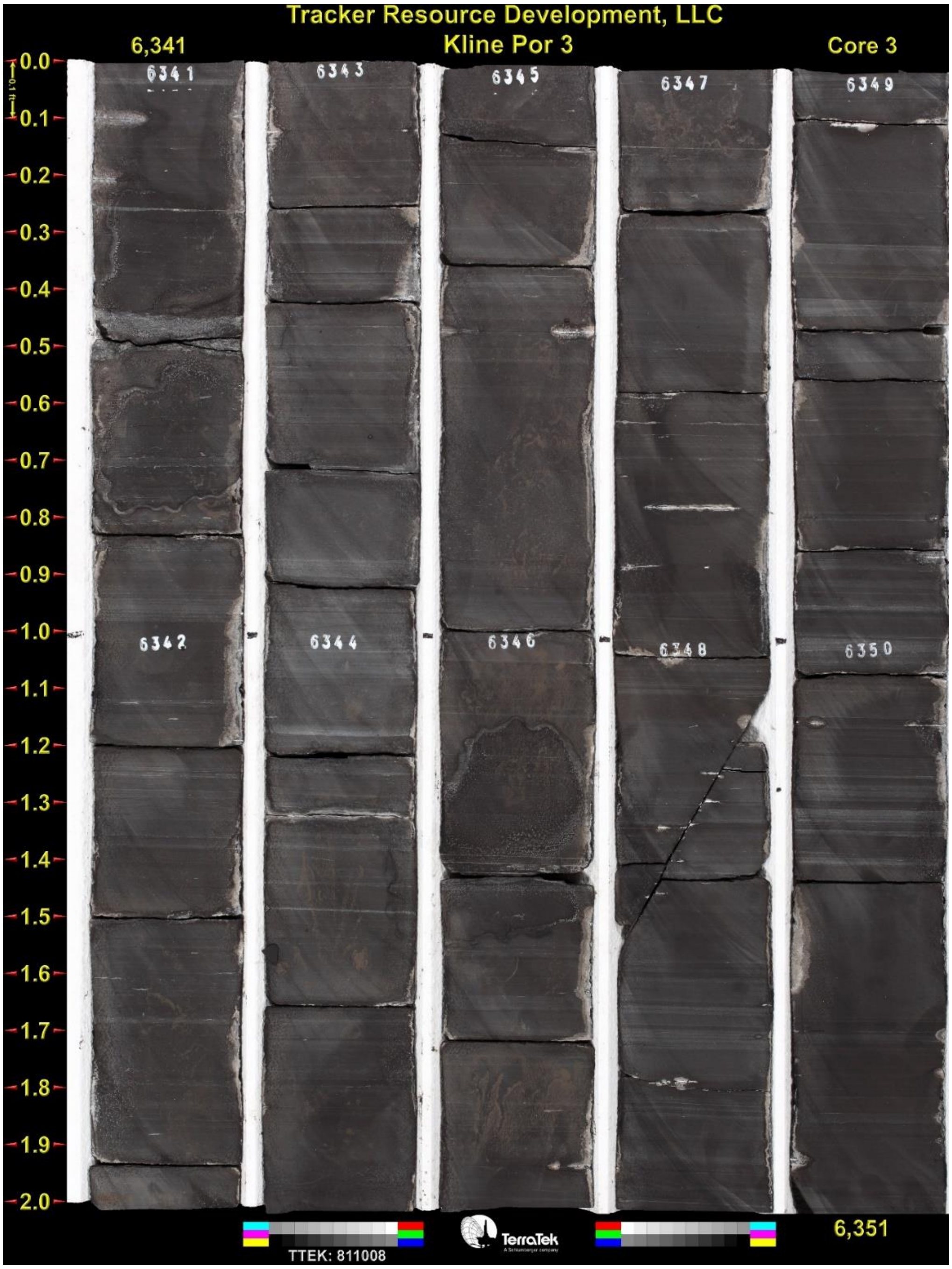
Slab pack core sample of Kline Por 3 well in Portage County, Ohio. Interval is 6,311-6,321 feet. Photos taken by Terra Tek.



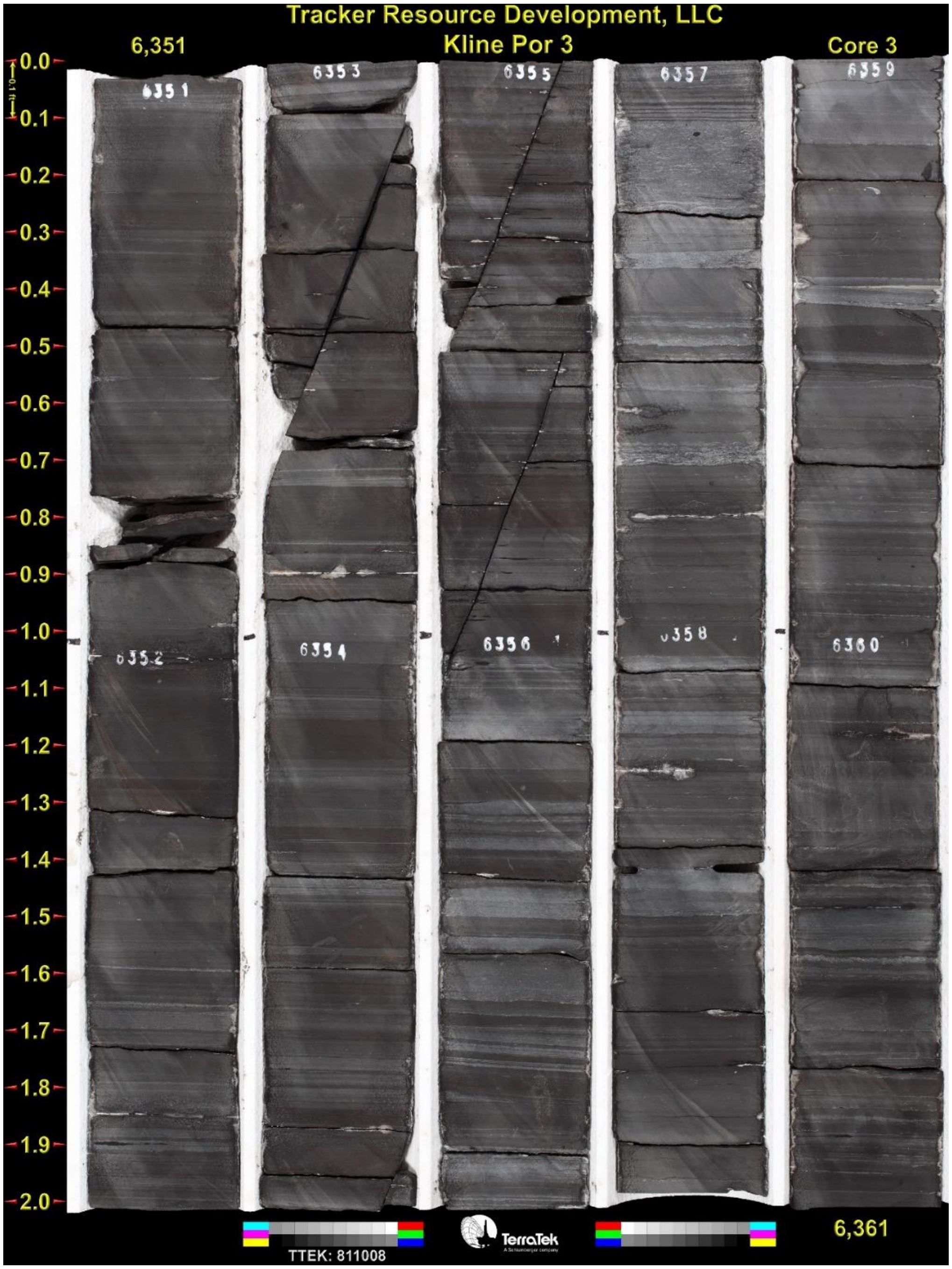
Slab pack core sample of Kline Por 3 well in Portage County, Ohio. Interval is 6,321-6,331 feet. Photos taken by Terra Tek.



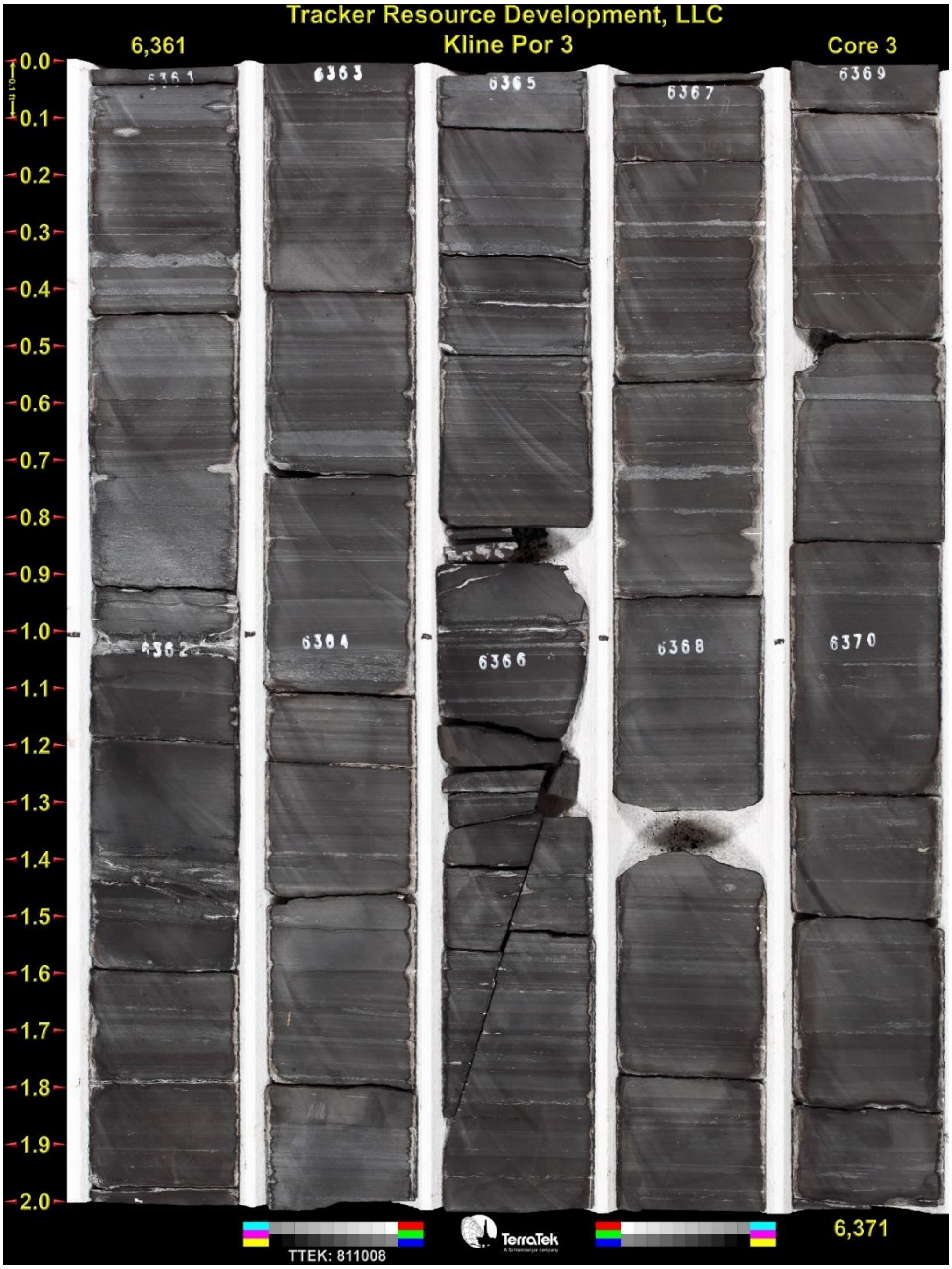
Slab pack core sample of Kline Por 3 well in Portage County, Ohio. Interval is 6,331-6,341 feet. Photos taken by Terra Tek.



Slab pack core sample of Kline Por 3 well in Portage County, Ohio. Interval is 6,341-6,351 feet. Photos taken by Terra Tek.

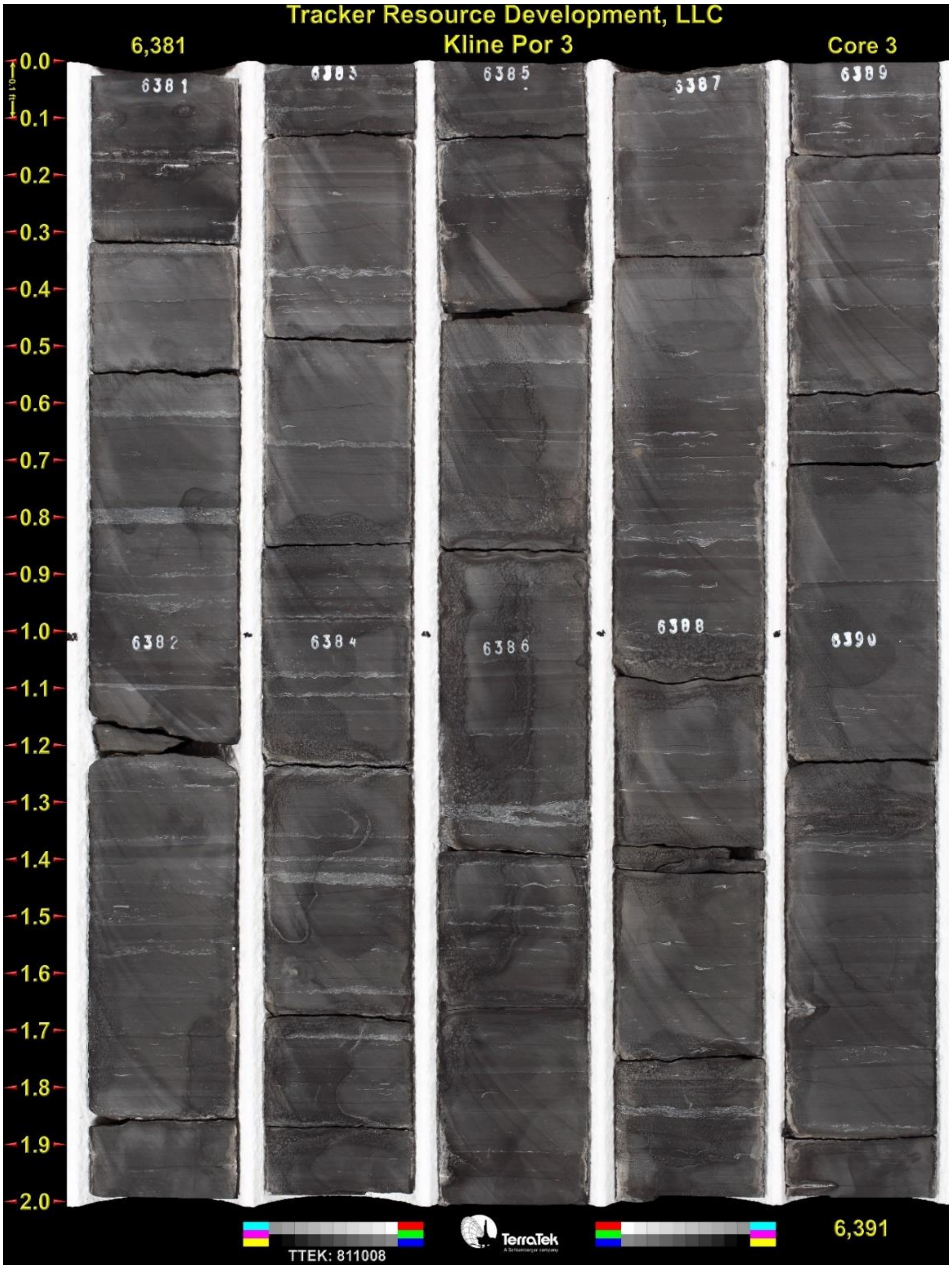


Slab pack core sample of Kline Por 3 well in Portage County, Ohio. Interval is 6,351-6,361 feet. Photos taken by Terra Tek.

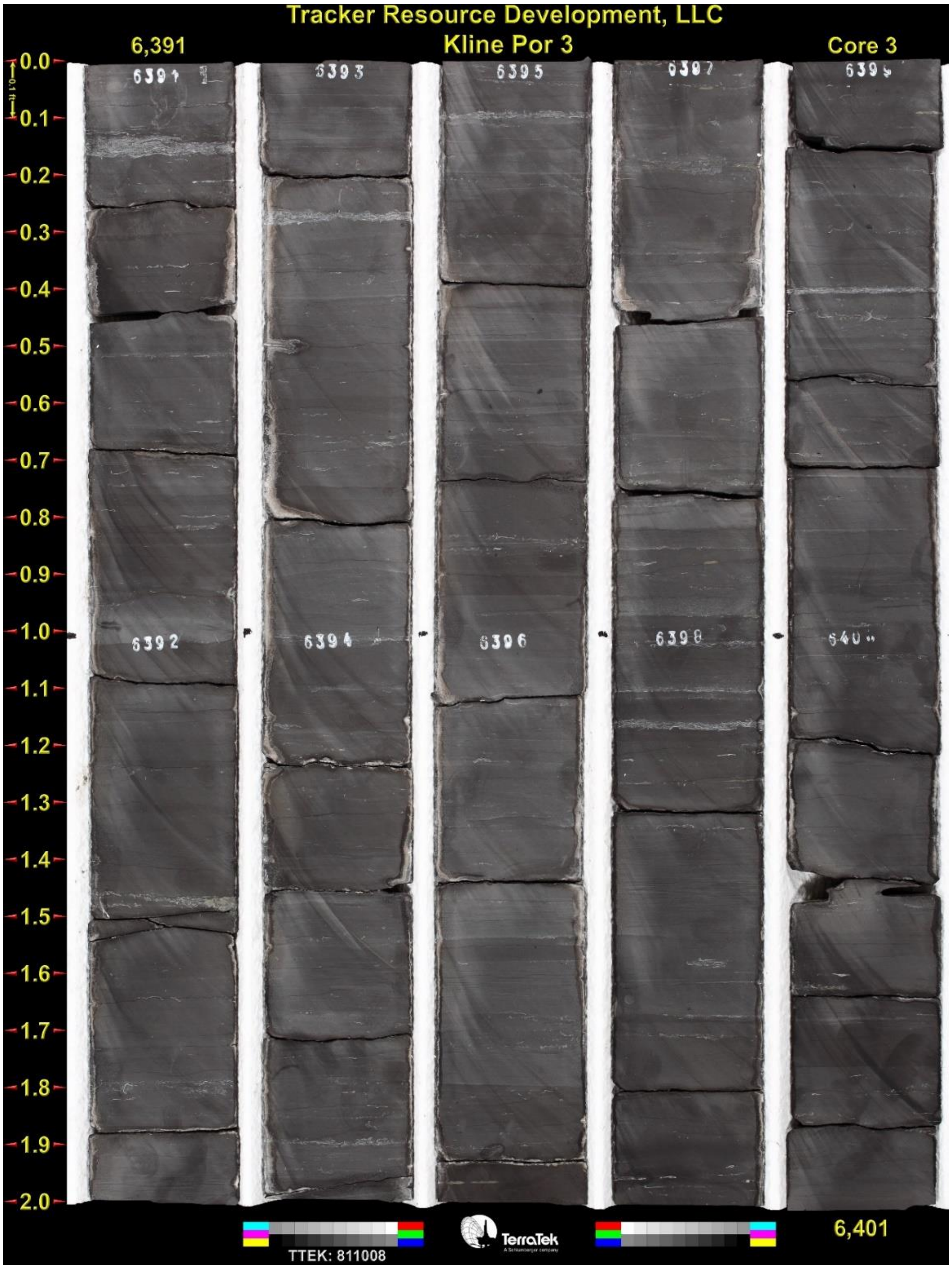


Slab pack core sample of Kline Por 3 well in Portage County, Ohio. Interval is 6,361-6,371 feet. Photos taken by Terra Tek.

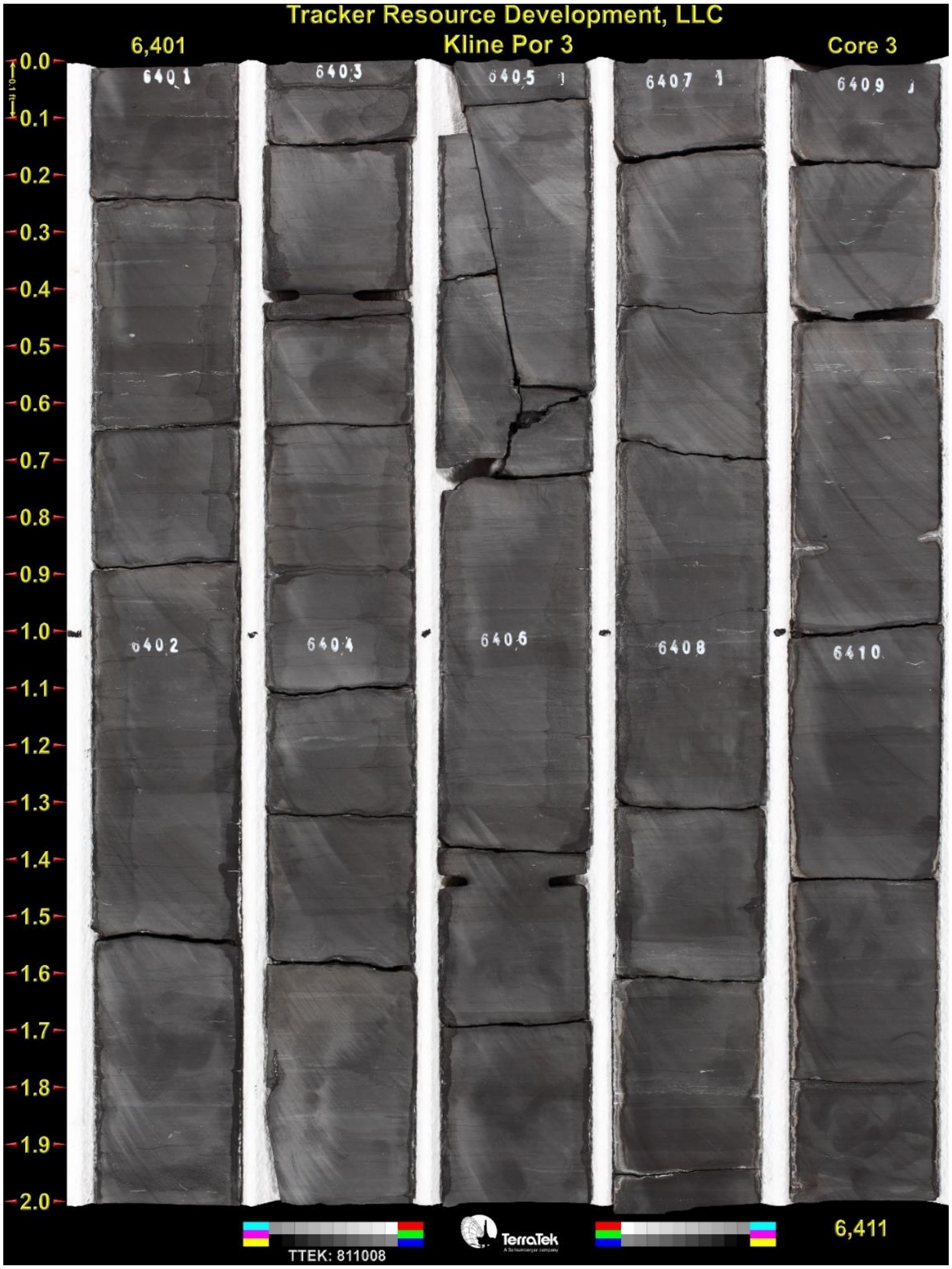
Slab pack core sample of Kline Por 3 well in Portage County, Ohio. Interval is 6,371-6,381 feet. Photos taken by Terra Tek.



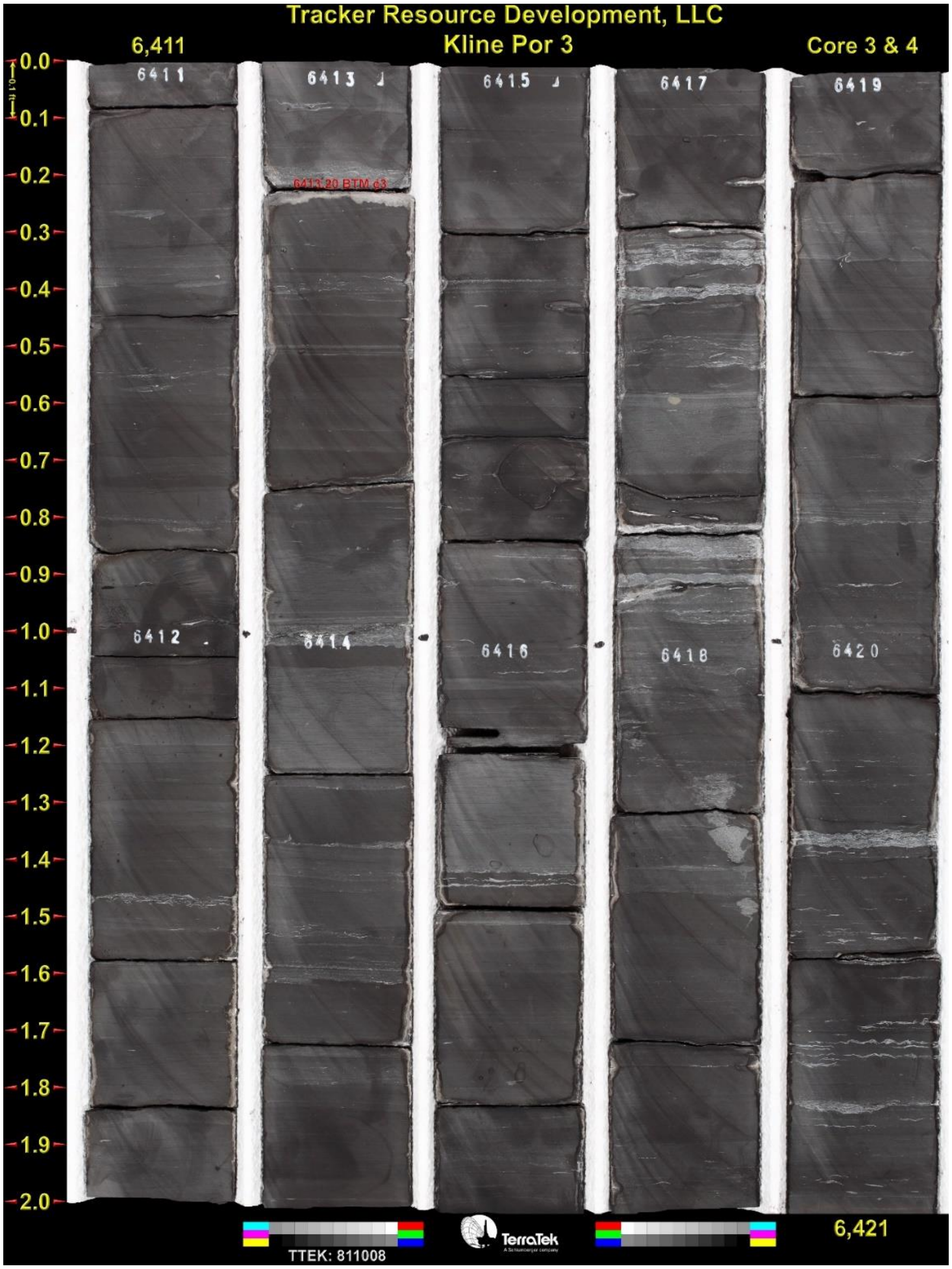
Slab pack core sample of Kline Por 3 well in Portage County, Ohio. Interval is 6,381-6,391 feet. Photos taken by Terra Tek.



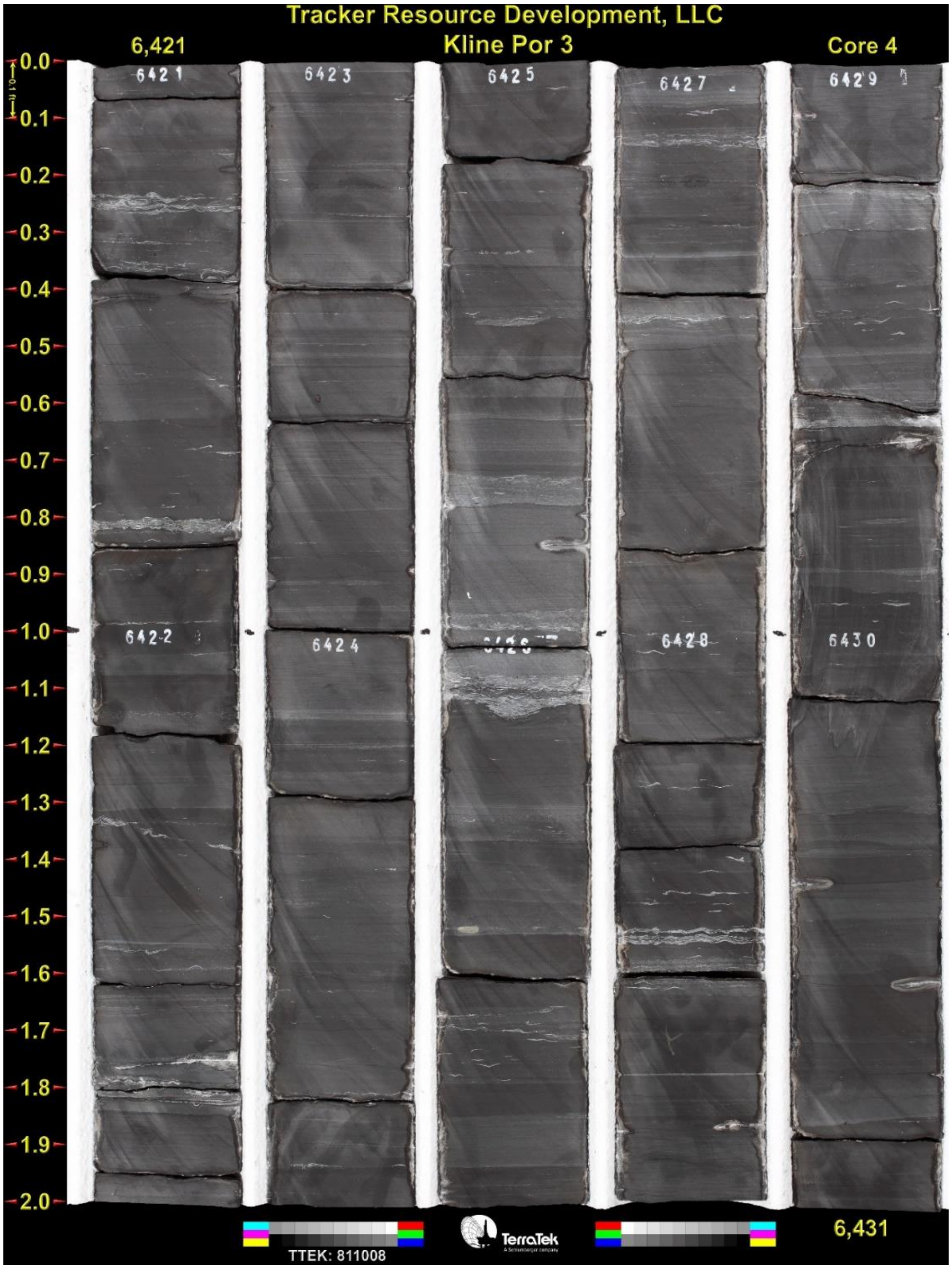
Slab pack core sample of Kline Por 3 well in Portage County, Ohio. Interval is 6,391-6,401 feet. Photos taken by Terra Tek.



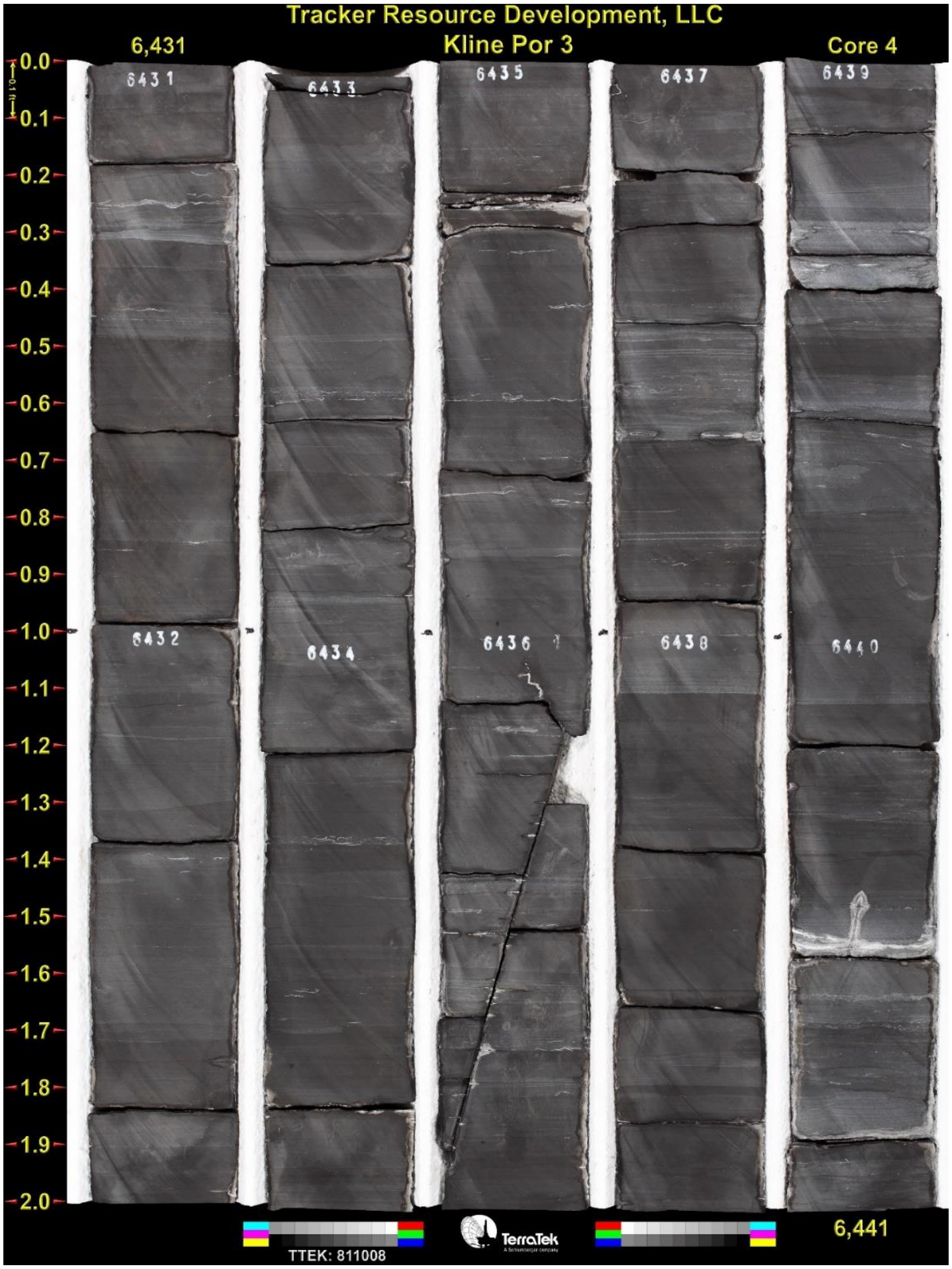
Slab pack core sample of Kline Por 3 well in Portage County, Ohio. Interval is 6,401-6,411 feet. Photos taken by Terra Tek.



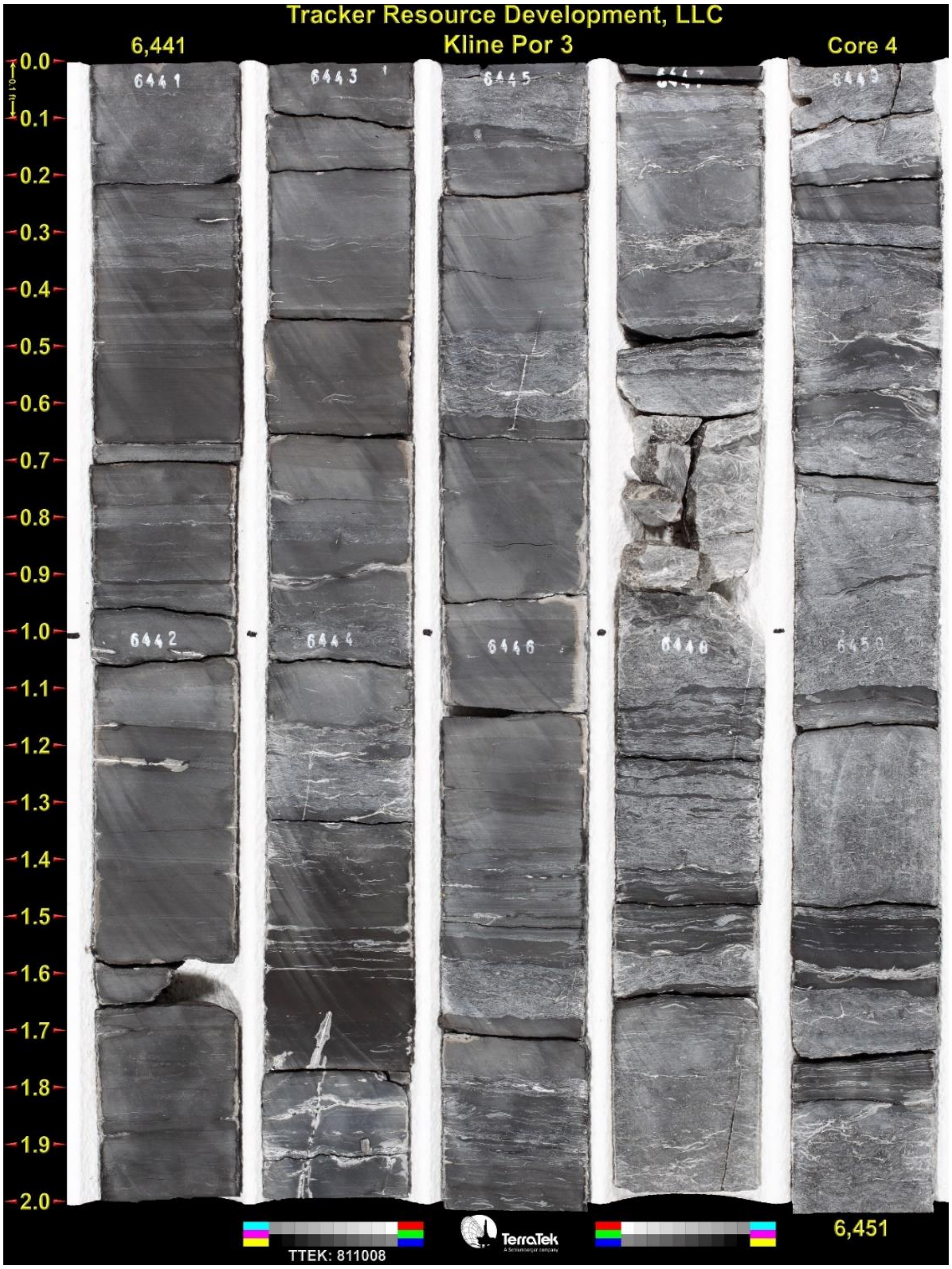
Slab pack core sample of Kline Por 3 well in Portage County, Ohio. Interval is 6,411-6,421 feet. Photos taken by Terra Tek.



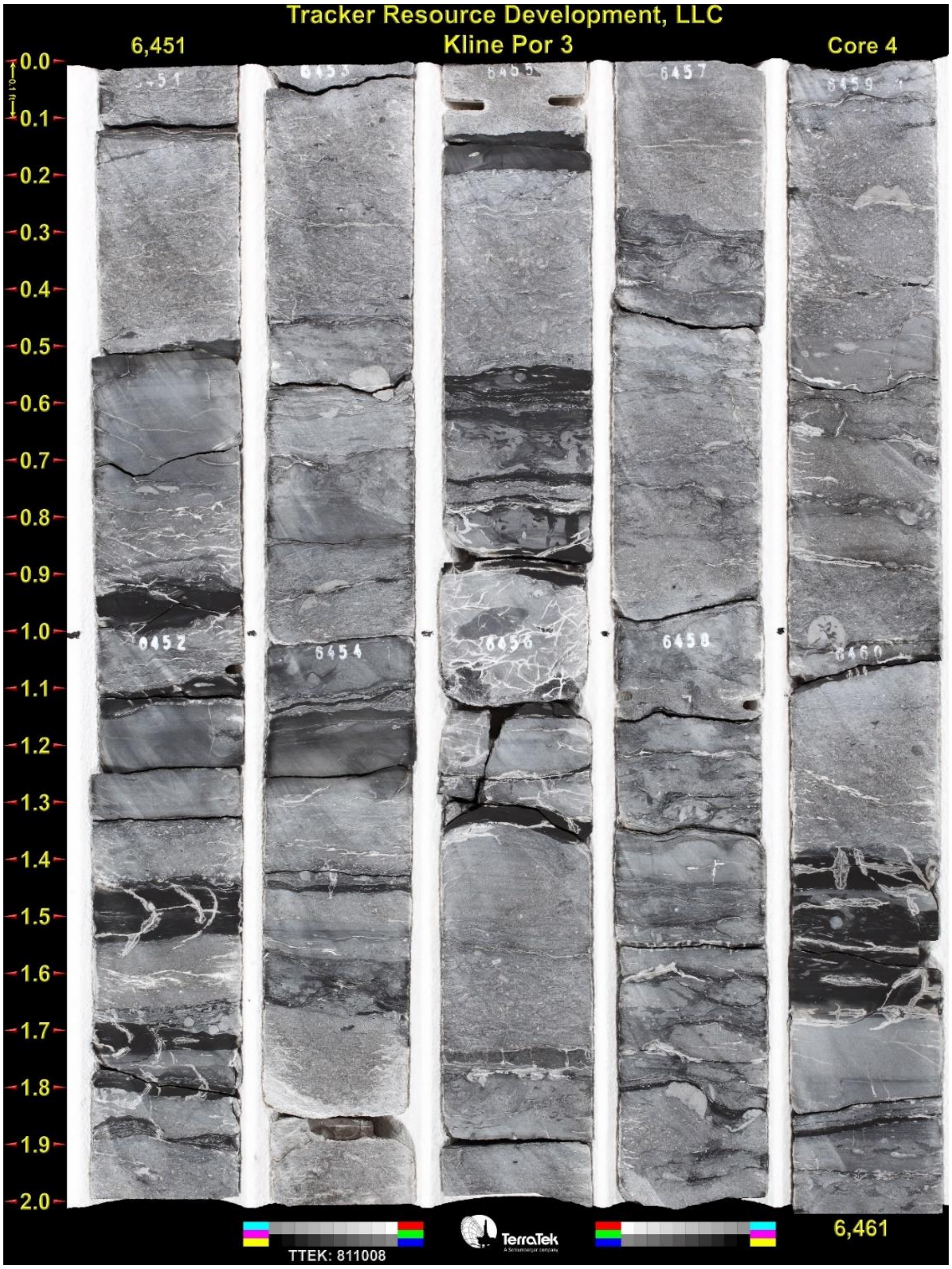
Slab pack core sample of Kline Por 3 well in Portage County, Ohio. Interval is 6,421-6,431 feet. Photos taken by Terra Tek.



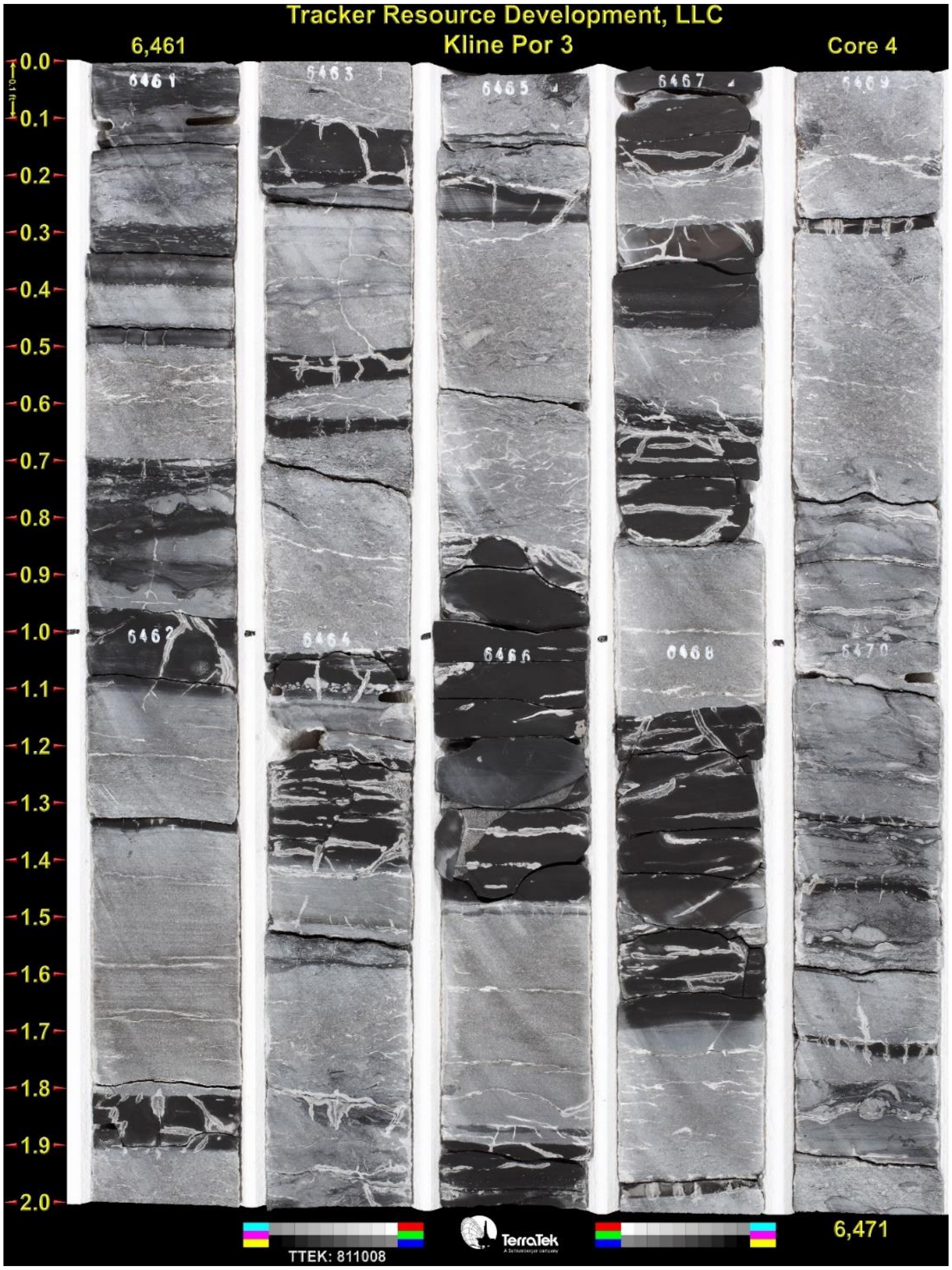
Slab pack core sample of Kline Por 3 well in Portage County, Ohio. Interval is 6,431-6,441 feet. Photos taken by Terra Tek.



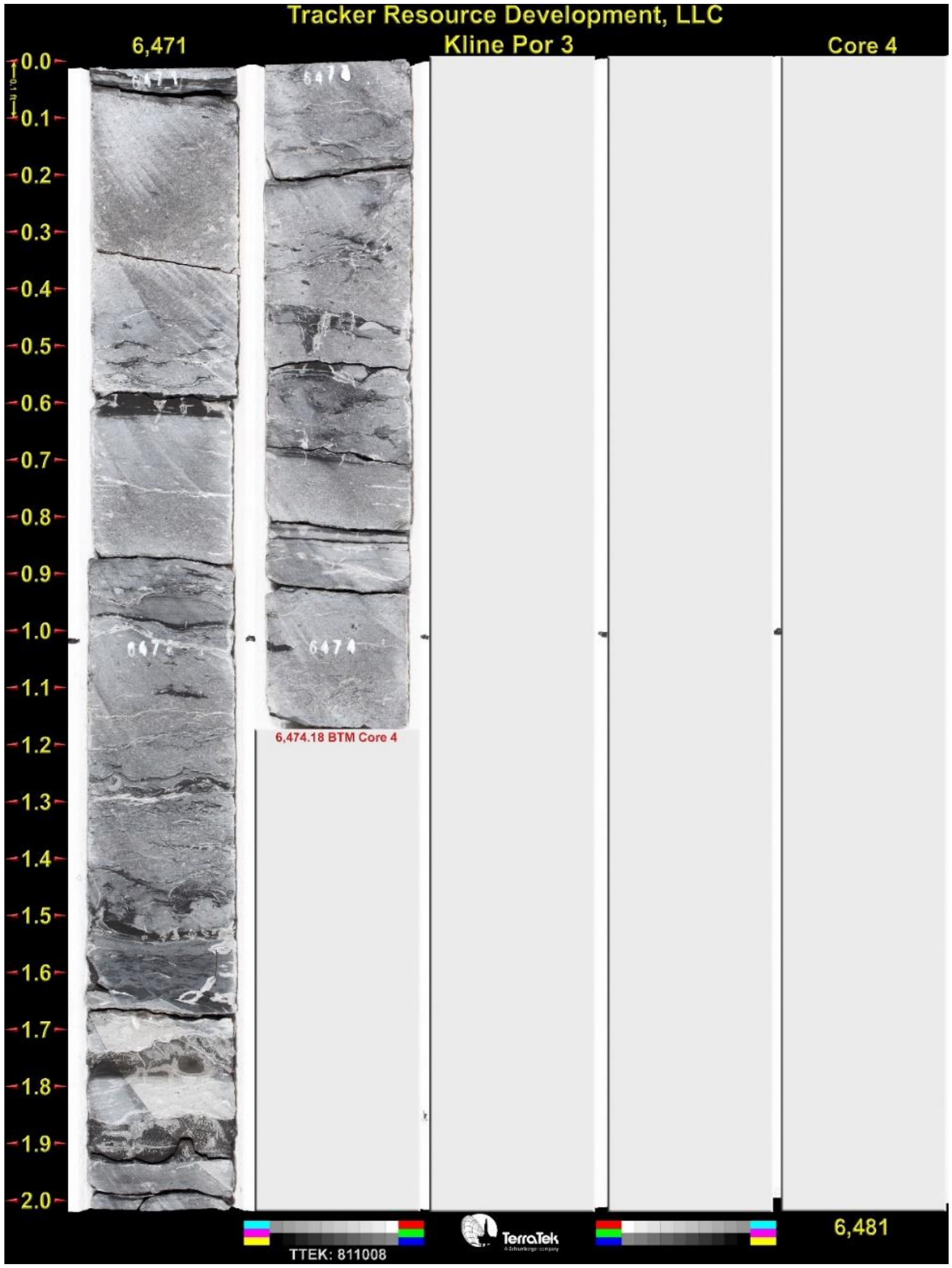
Slab pack core sample of Kline Por 3 well in Portage County, Ohio. Interval is 6,441-6,451 feet. Photos taken by Terra Tek.



Slab pack core sample of Kline Por 3 well in Portage County, Ohio. Interval is 6,451-6,461 feet. Photos taken by Terra Tek.



Slab pack core sample of Kline Por 3 well in Portage County, Ohio. Interval is 6,461-6,471 feet. Photos taken by Terra Tek.



Slab pack core sample of Kline Por 3 well in Portage County, Ohio. Interval is 6,471-6,474 feet. Photos taken by Terra Tek.

Appendix 5. Core descriptions from the Tracker Resource Development Kline Por 3 well. The descriptions were made to observe the overall transition from formation to formation. Depth values are in feet and are based on depths labeled on the core.

6,473-6,474

Light to medium grey in color limestone with laminated fossils. At ~6,473' 5-6", a bed that was made by an organism and created a bed and burrow that was filled in with medium-dark shale. Microcrystalline quartz is common throughout the interval.

6,472-6,472

Mostly limestone with a few thick shale layers as seen at 6,472' 8" to 6,473'. The shale layers are medium to dark gray in color. Limestones are light to medium gray in color. The layers alternate starting with shale, fossiliferous limestone, shale, fossiliferous limestone. Laminated fossil beds are present. Microcrystalline quartz is abundant in limestone above the alternating shale-fossiliferous limestone beds.

6,469-6,472

Limestone with some shale layers in the core. The fossiliferous limestones is light to medium grey in color. The shale is medium to dark grey in color. Laminations of fossils continue up section. There are two layers of storm beds that display high energy conditions. Microcrystalline quartz is less abundant in this interval. A bed of rip up clasts are found at 6,472'.

6,461-6,469

This section is predominately fossiliferous limestone (70%). The limestone is light to medium gray in color. The shale is medium to dark gray in color. There are thin laminations made of fossils throughout the interval. At 6,464', there is a fossil bed with the fossils oriented in a laminar manner. This seems to be a bed of fossils that were overlain by shale and buried/compacted. The fossils are whole with a rugose coral fossil present below the bed. Calcite is abundant throughout the fossiliferous limestone. There are a few calcite lenses with the limestone.

6,451-6,460

This section is ~80% limestone and 20% shale. There are noticeable storm beds (ex. bottom of 6,455, top 6,454, bottom 6,452). The storm beds of 6,454' and 6,455' look to be high energy storm bed. The tiny, broken fossils are the indication of high energy. The storm bed of 6,452' looks low energy because of the whole fossils. These fossils are compacted and buried. There is a brachiopod at the bottom of 6,459. Colors of shale and limestone are similar to the sections already mentioned. Calcite is present as a replacement mineral in fossils. Calcite filled fractures continue to show in this section.

6,444-6,450

This section is primarily limestone (80%) and shale (20%). The limestone becomes less fossiliferous as the core shallows. Calcite crystals become less abundant in the center but show up on edges of the core slab. There are storm deposits present and can range up to 10 cm (4 in).

6,384-6,444

The bottom section is primarily calcareous shale with some thin limestone. The calcareous shale is medium to dark grey in color. The limestone is medium to dark in color. There is a little amount of fossils present in the section. Storm deposits are visible along with shell laminated beds. None, if not many, crystalline quartz are in the section. Pyrite is visible at 6,392'.

6,357-6,384

The upper section of the Point Pleasant is mainly calcareous shale. The calcareous shale is medium to dark grey in color. There are commonly occurring storm beds. There is pyrite in the sections either as nodules but also fragments within storm beds. The pyrite is mostly secondary replacement but can be primary. There is a fracture in the core at 6,366'. There are some minor whole fossils in the core. Graptolites, brachiopods, and crinoid stems are common within the section.

6,324-6,357

Lower section of the Utica shale is 80% calcareous shale. The shale is medium to dark gray in color. There are thin laminations of light grey limestone. Storm beds are still frequent but are thinner. Pyrite is still common either as nodules or thin lenses. They are also common in the thin storm beds. Fractures in the core are becoming more frequent as you move up section. Fossils become less frequent in the middle of the section. Graptolites are prevalent at tops of core slabs (ex 6,321').

6,265-6,324

The middle to lower section of the Utica is primarily shale with some thin limestone laminations. This section is abundant in fossils with some whole pieces (30%) and the rest are broken (70%). The storm beds within the section are made of mostly broken crinoids and brachiopods. There are some fossils beds that look to be buried and compacted. The fossils have secondary calcite infills. Some of the fossils also have pyritic rims which suggest the pyrite was later than calcite in diagenesis (ex 6,287' and 6,290'). Calcite is present on the edges of the core slabs, excluding the fossil infills. Fractures are common in the lower portion but are gone from the middle section to the top of the Utica core section.

6,204-6,265

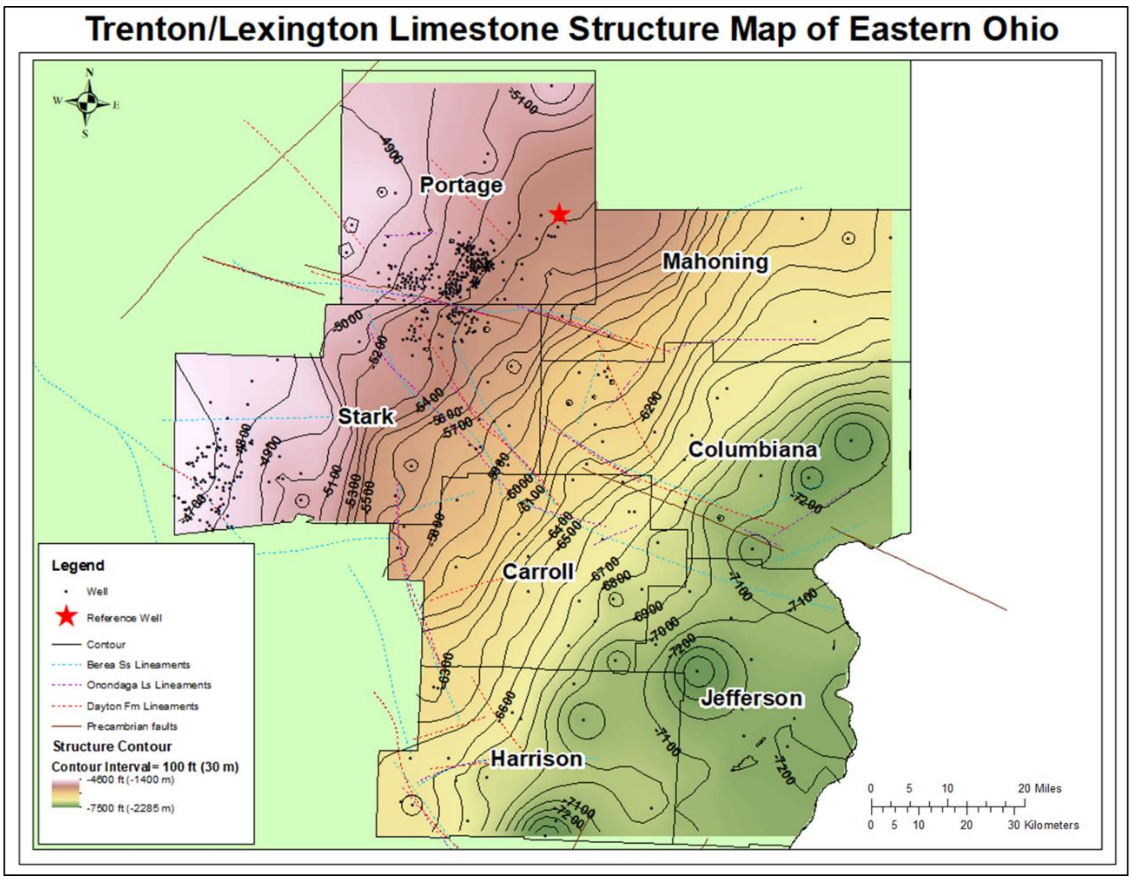
The lower part of the section display a tilted bedding. The lower four feet is very fossiliferous and begins to lessen up section. There are storm beds with broken fossils from 6,246'-6,260 but are not abundant. Crinoid and brachiopod fossils are whole and broken. Shale is the most abundant with thin limestone laminations. Limestone laminations become more frequent in the upper part of the section. Shell hash beds are more abundant in the upper section. Whole fossils become less abundant up section. Graptolites are found at the top of the section core slab.

6,141-6,204

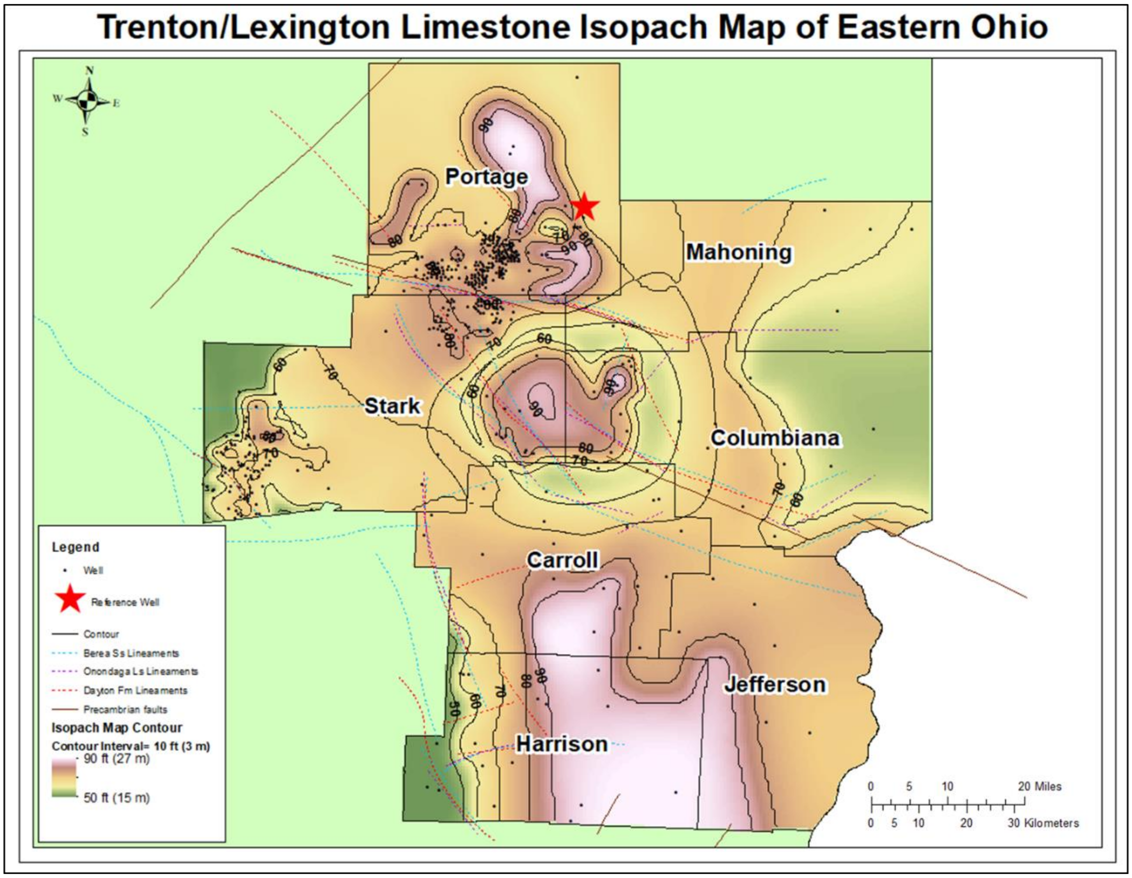
The shale is medium to dark in color. The color alternates from medium to dark gray at the top of the section. Fossils are not common in this section but some are present. Thin fossil layers and shell hash beds are present with shell hash beds being more abundant.

Shell hash beds become less abundant moving up section. Limestone layers are thin. Fractures in the core are visible, but are not abundant.

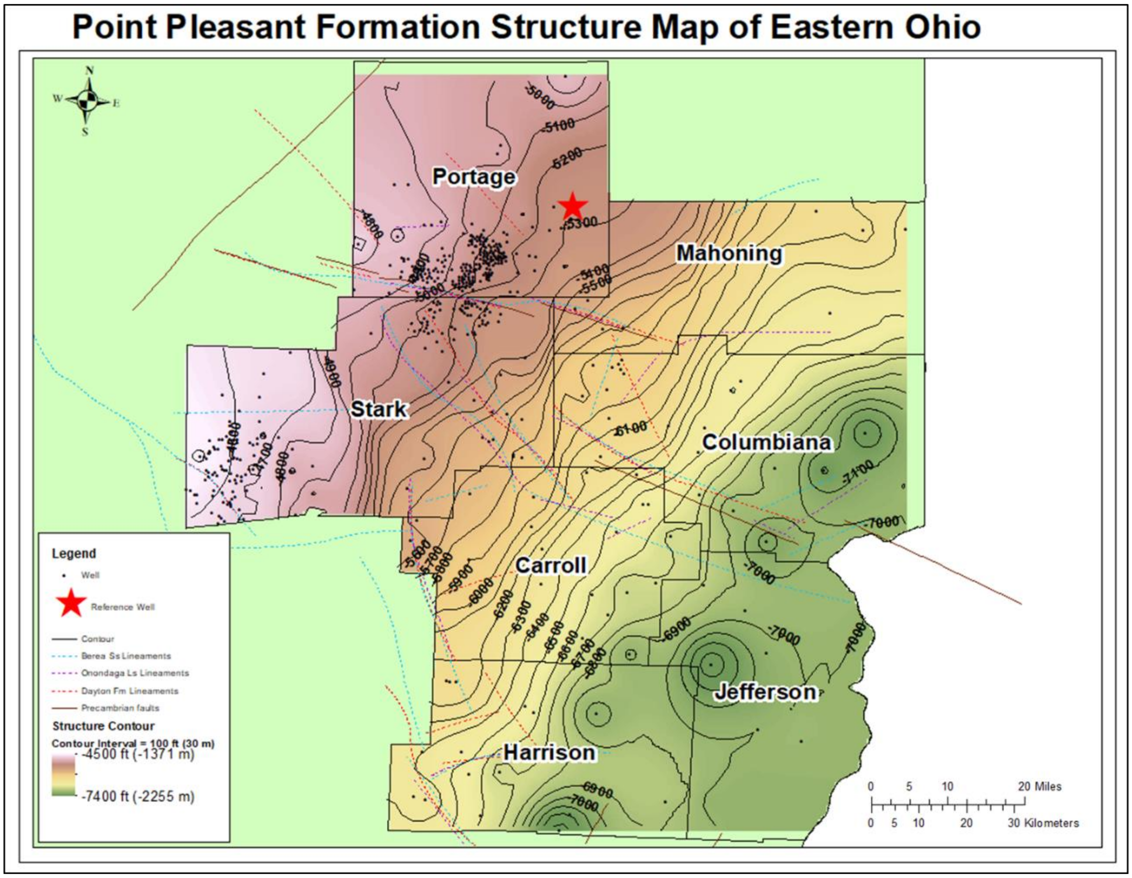
Appendix 6. Unedited structure and isopach maps. Contours and raster's were created by ArcGIS.



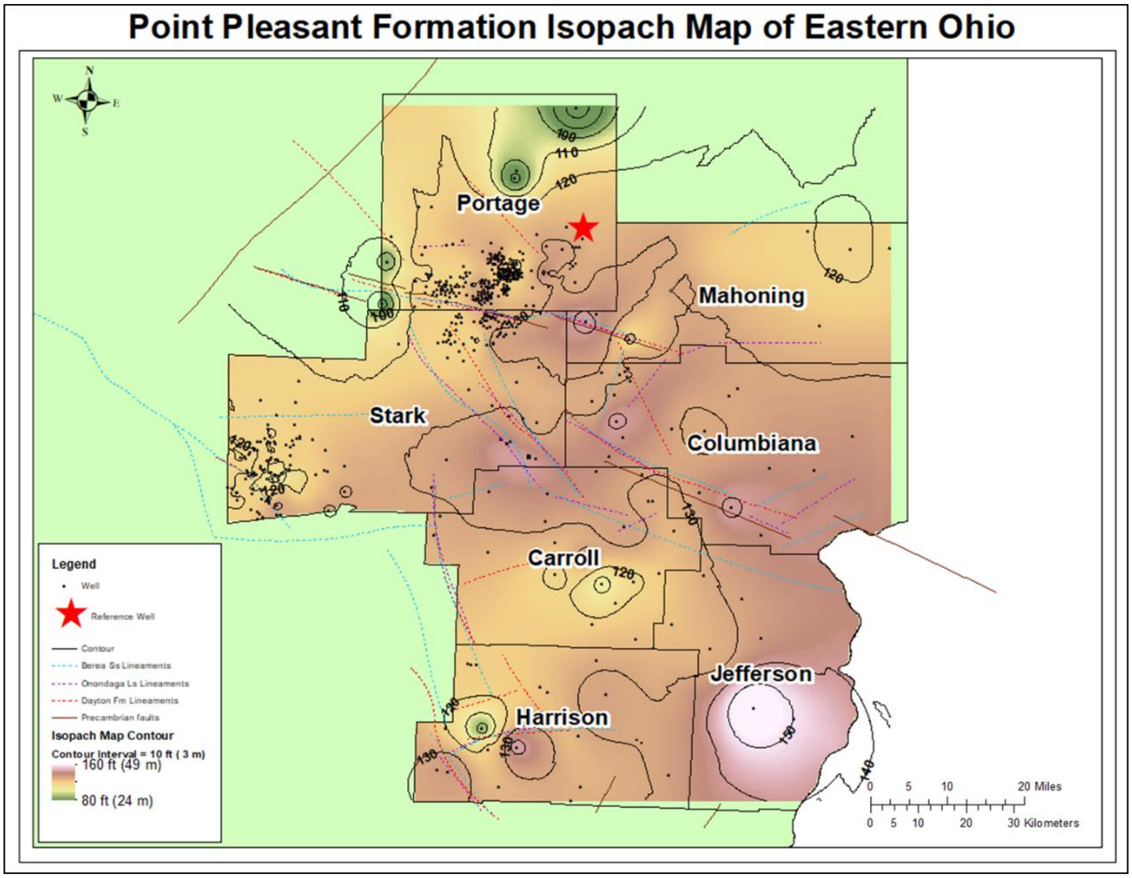
Root Mean Square=72.99. Regressive function= 0.951352616642483*x+-249.731019936912



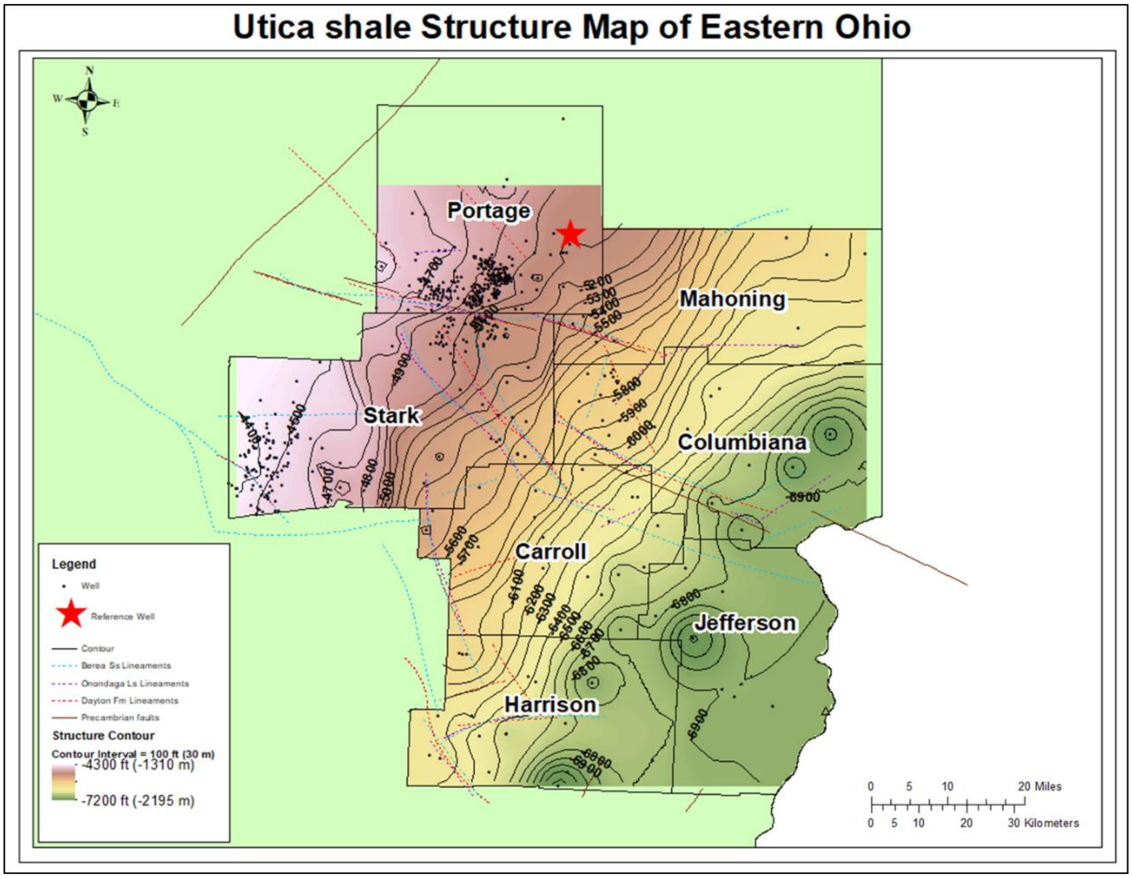
Root Mean Square= 6.469127. Function= 0.300592231975973*x+52.5560550541898



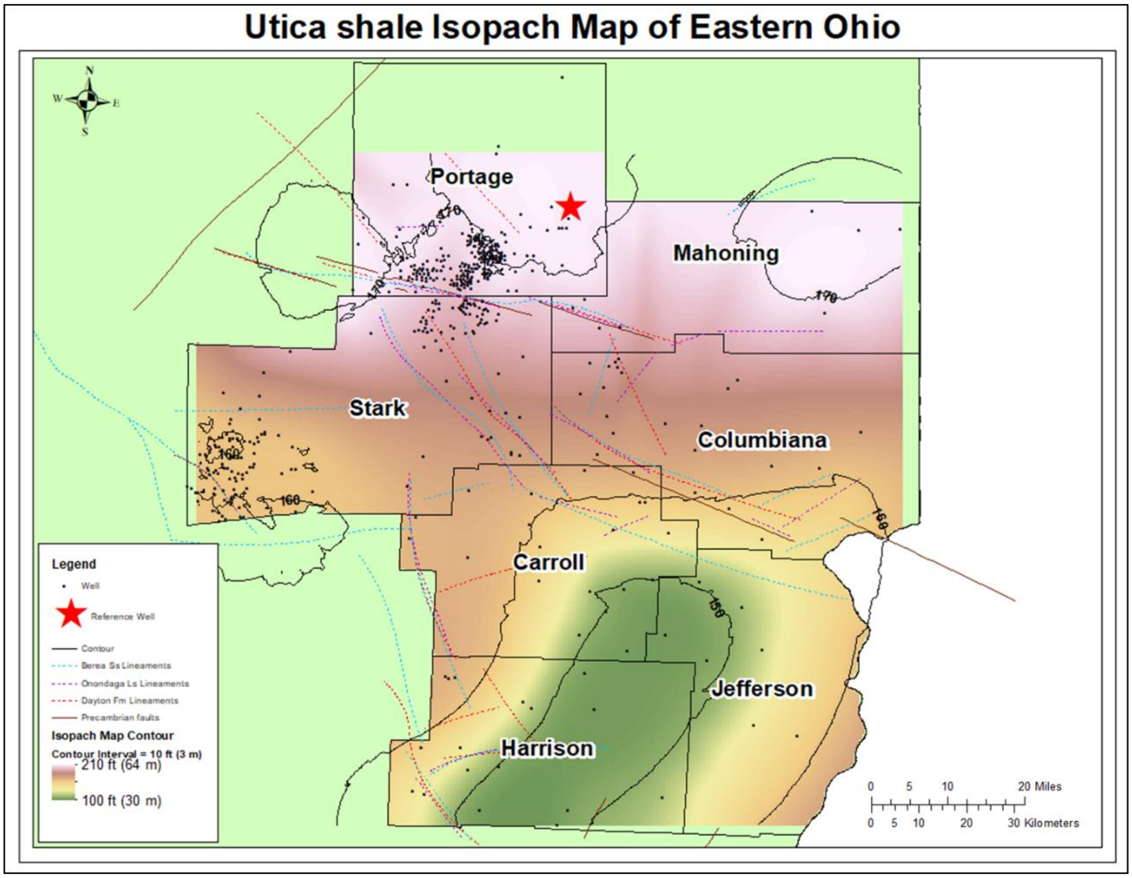
Root Mean Square= 88.26. Function= 0.957068042009197*+x-215.627576511062



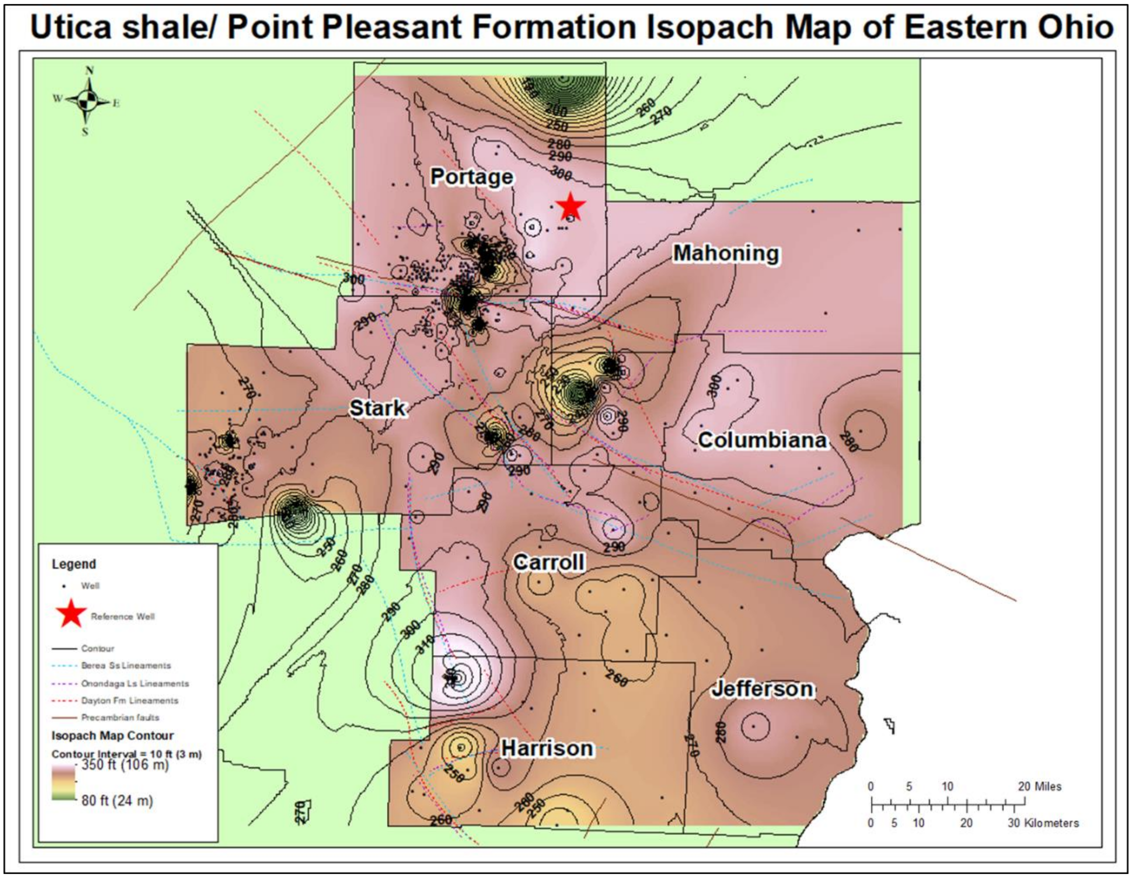
Root Mean Square= 8.34. Function= 0.226589634379135*x+96.4068462773106



Root Mean Square=90.48. Function=0.95447259971021*x+-220.590645594991

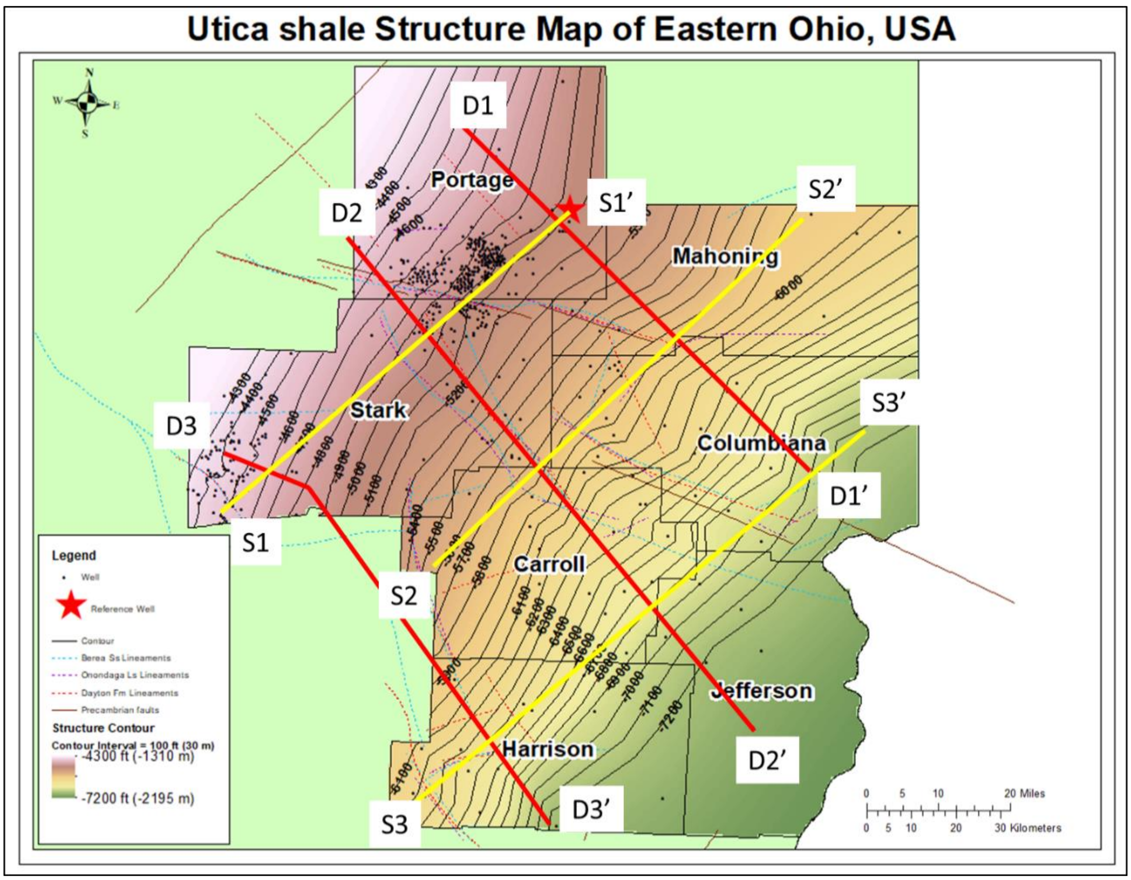


Root Mean Square=9.19. Function=0.465060966282097*x+88.5455839942933

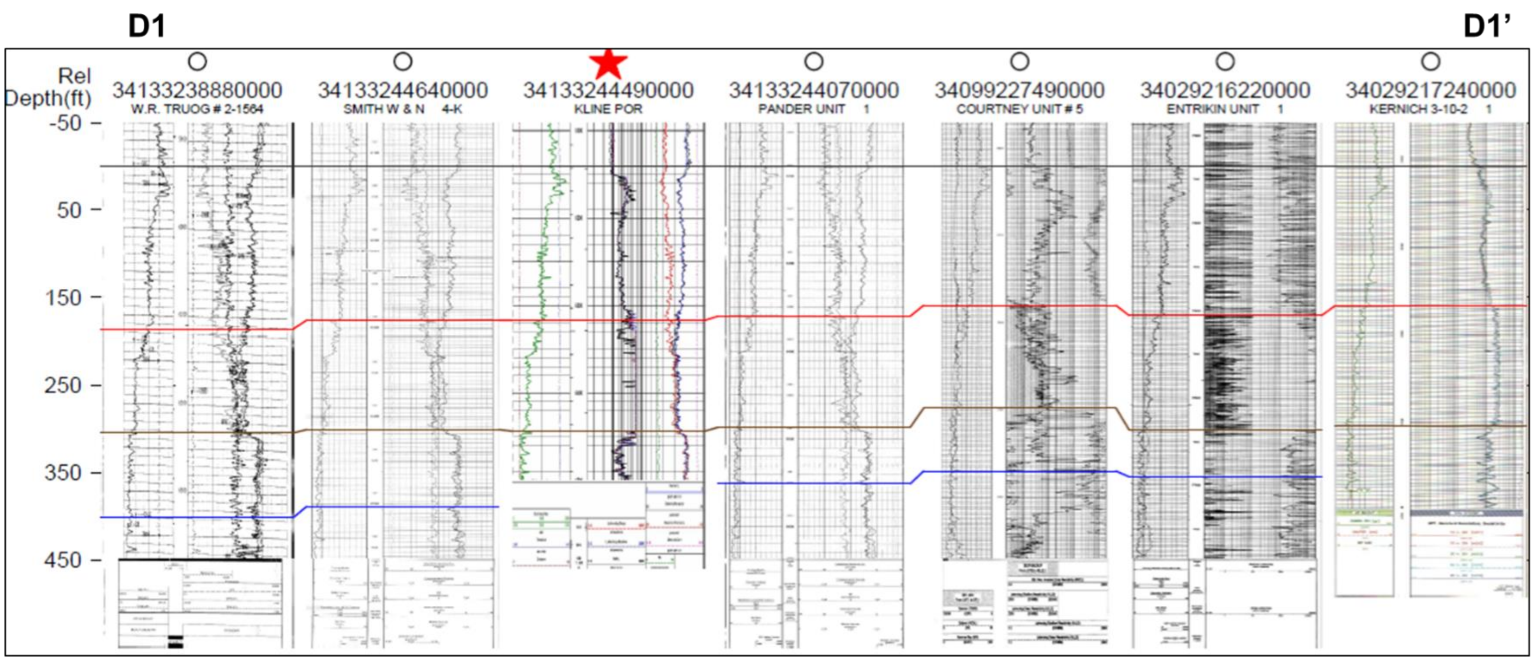


Root Mean Square= 42.37. Function= 0.0251211479349394*x+276.669257556273

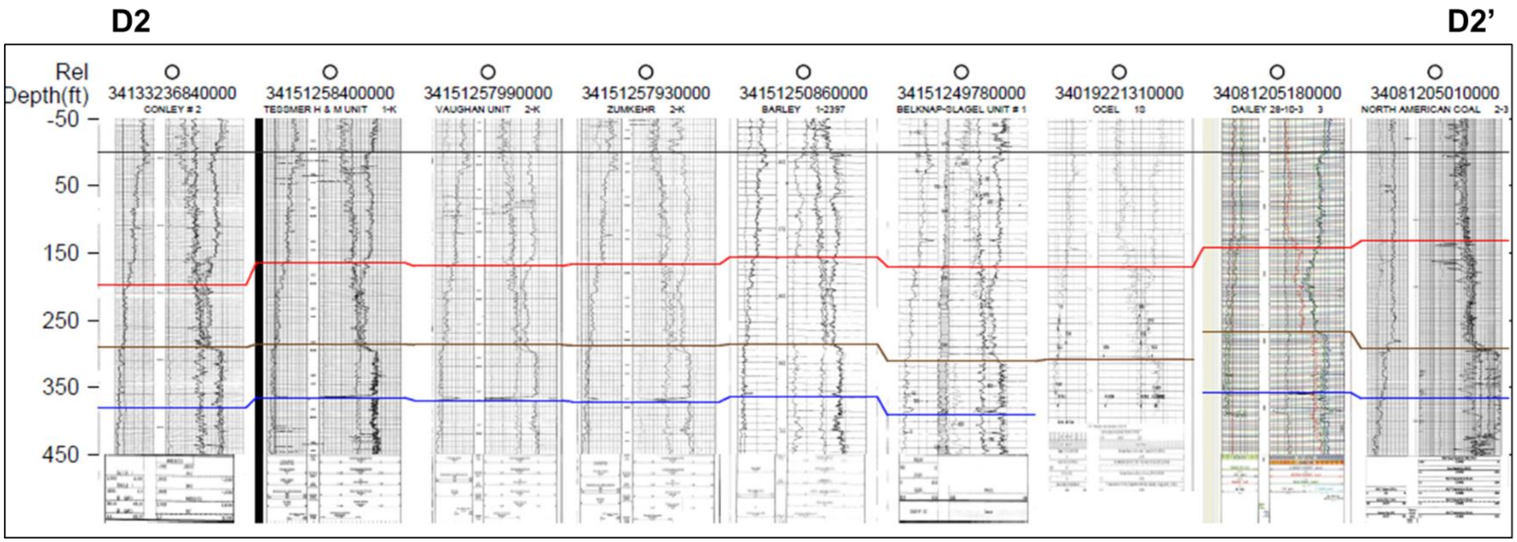
Appendix 7. Cross sections made to display thickening and thinning of each formation throughout the study area.



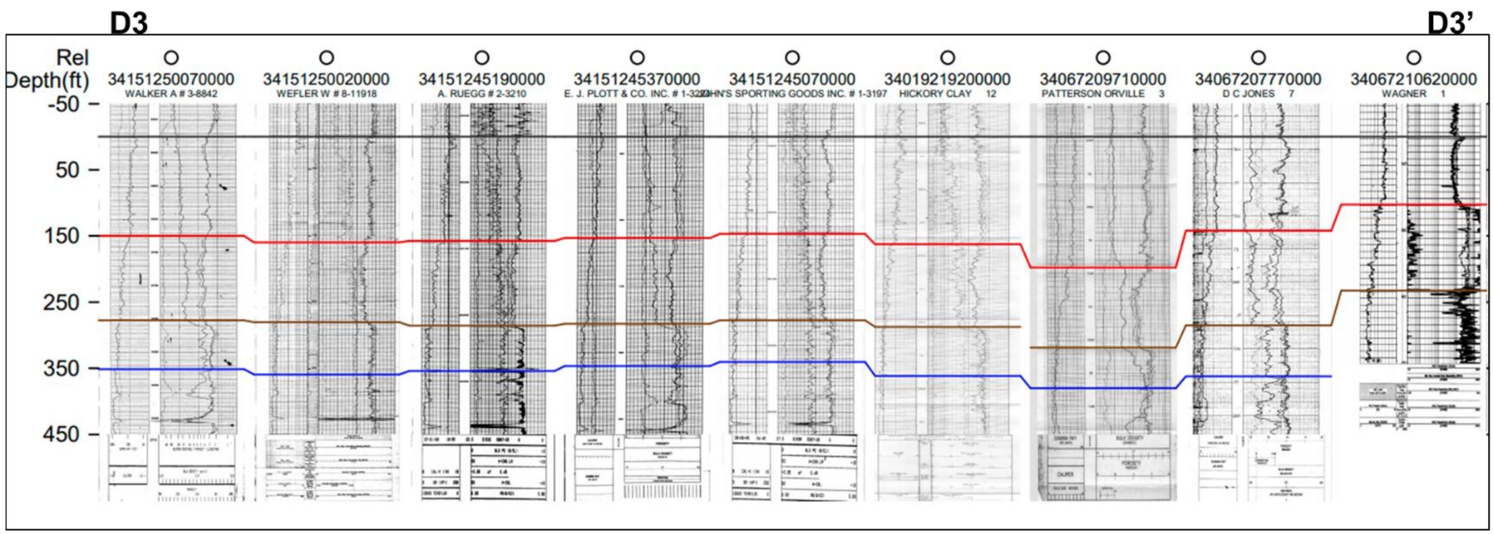
Utica structure map used to show the cross section lines. Three were made along strike and three were made along dip.



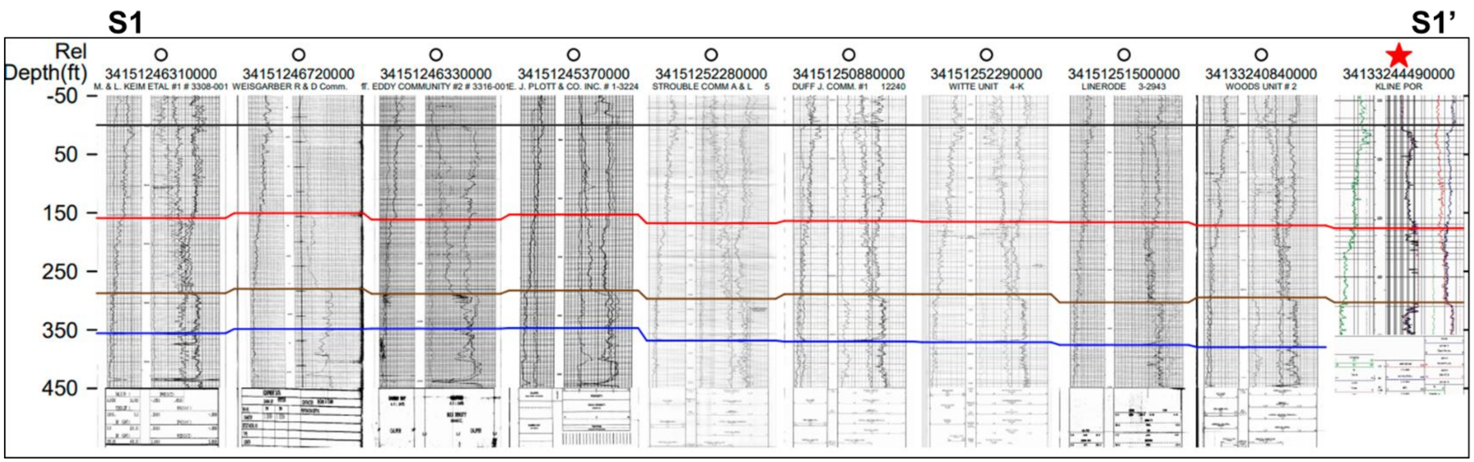
Black Line= Utica shale; Red Line= Point Pleasant Fm.; Brown line= Trenton/Lexington Limestone; Blue Line= Black River Limestone



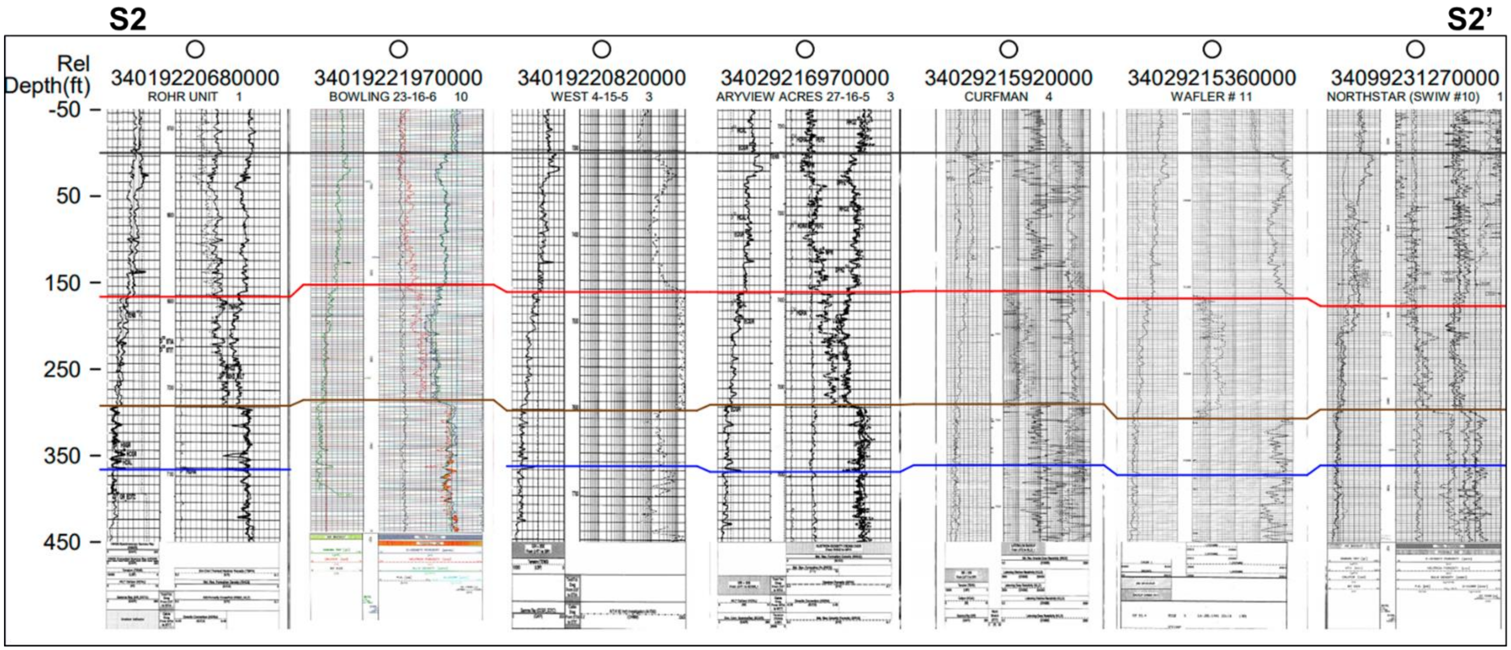
Black Line= Utica shale; Red Line= Point Pleasant Fm.; Brown line= Trenton/Lexington Limestone; Blue Line= Black River Limestone



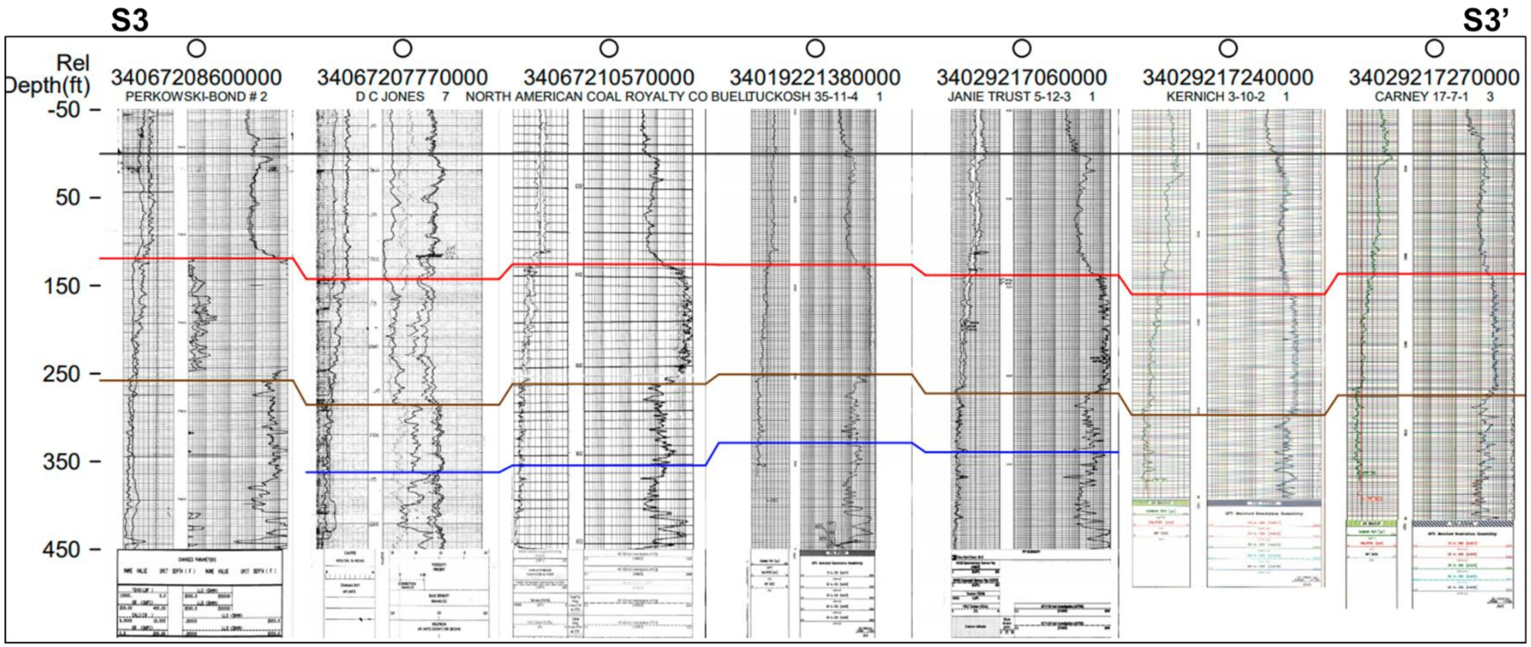
Black Line= Utica shale; Red Line= Point Pleasant Fm.; Brown line= Trenton/Lexington Limestone; Blue Line= Black River Limestone



Black Line= Utica shale; Red Line= Point Pleasant Fm.; Brown line= Trenton/Lexington Limestone; Blue Line= Black River Limestone



Black Line= Utica shale; Red Line= Point Pleasant Fm.; Brown line= Trenton/Lexington Limestone; Blue Line= Black River Limestone



Black Line= Utica shale; Red Line= Point Pleasant Fm.; Brown line= Trenton/Lexington Limestone; Blue Line= Black River Limestone

10. VITA

William K. Kirk graduated from Garrison High school in Garrison Texas in May 2014. He then enrolled to Centenary College of Louisiana in Shreveport, Louisiana. During his junior year, he completed an independent research of the Snake River Plain Basalts in Idaho. His senior year, he completed an independent research of the Mitchell Dam Amphibolite's in Chilton County, Alabama and presented the research at GCAGS 2018 in Shreveport, Louisiana. He graduated with his Bachelor of Science in Geology in May 2018 from Centenary College of Louisiana. He then enrolled in Stephen F. Austin State University Graduate School of Geology in Nacogdoches, Texas. He completed internships with oil and gas companies called Stroud Exploration in Shreveport, Louisiana as well as an internship with Tanos Exploration in Tyler, Texas. He graduated with his Master of Science in Geology from Stephen F. Austin State University in May 2021. He went on to pursue a career in the oil and gas industry.

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Thesis Manual Designation: APA Format

This thesis was typed by William K. Kirk